Snowmelt Parameterisation of Land Surface Hydrological Models in Subarctic and Arctic Basins

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Parameterisation: Perspectives and Approaches
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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

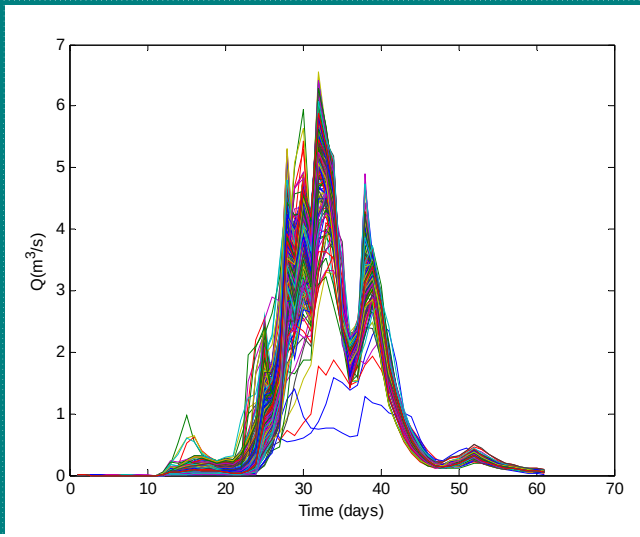
    Can account for spatial patterns of process response

Complexity → more parameters

Not enough data

Some parameters still conceptual

Equifinality issues



Scale issues in Hydrological Modelling

- Hydrological process at a range of scales

  Small length scales area associated with small times

  Large length scales area associated with large times

- Not always happens

Infiltration excess → Point scale phenomena

Saturation excess → Lateral flow → Area associated with the process

- Mismatch between scales
  - **Observation scales**
  - **Process scales**
  - **Modelling scales**

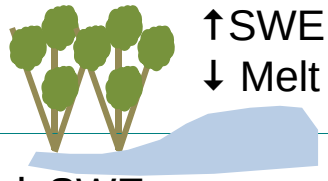
Scaling (up-down)
Transference of information

- Scaling is limited by spatial heterogeneity and variability in hydrological process environments. **Effective parameters**.

Scale issues in Hydrological Modelling

Small scale

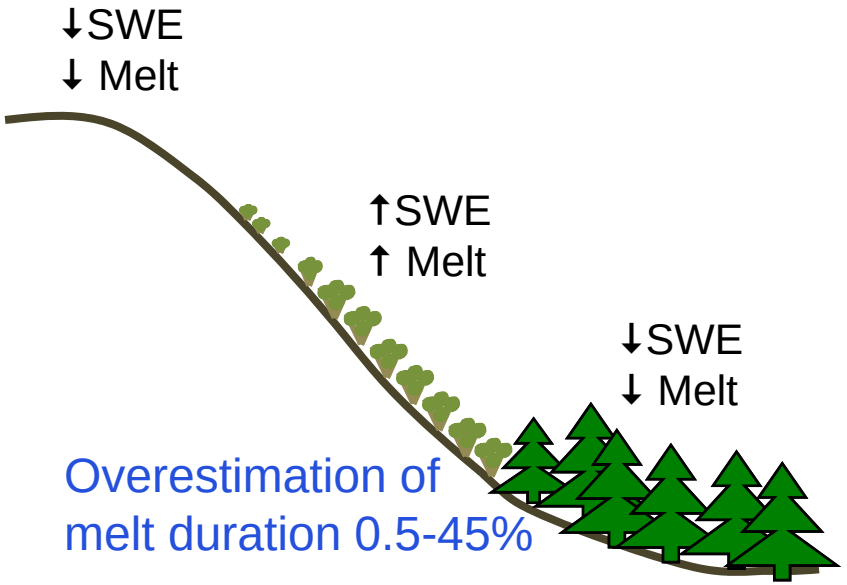
Negative association Melt-SWE



Underestimation of melt duration 14%

Large (basin) scale

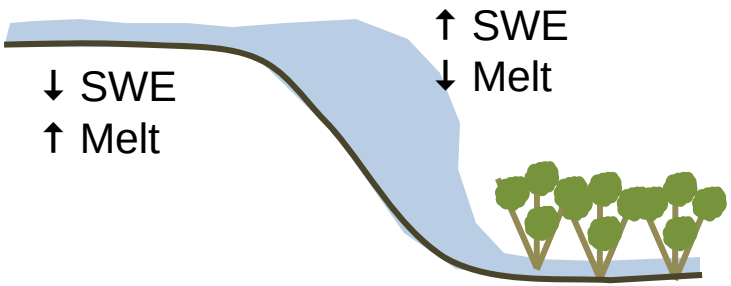
Positive association M-SWE



Overestimation of melt duration 0.5-45%

Medium (Landscape) scale

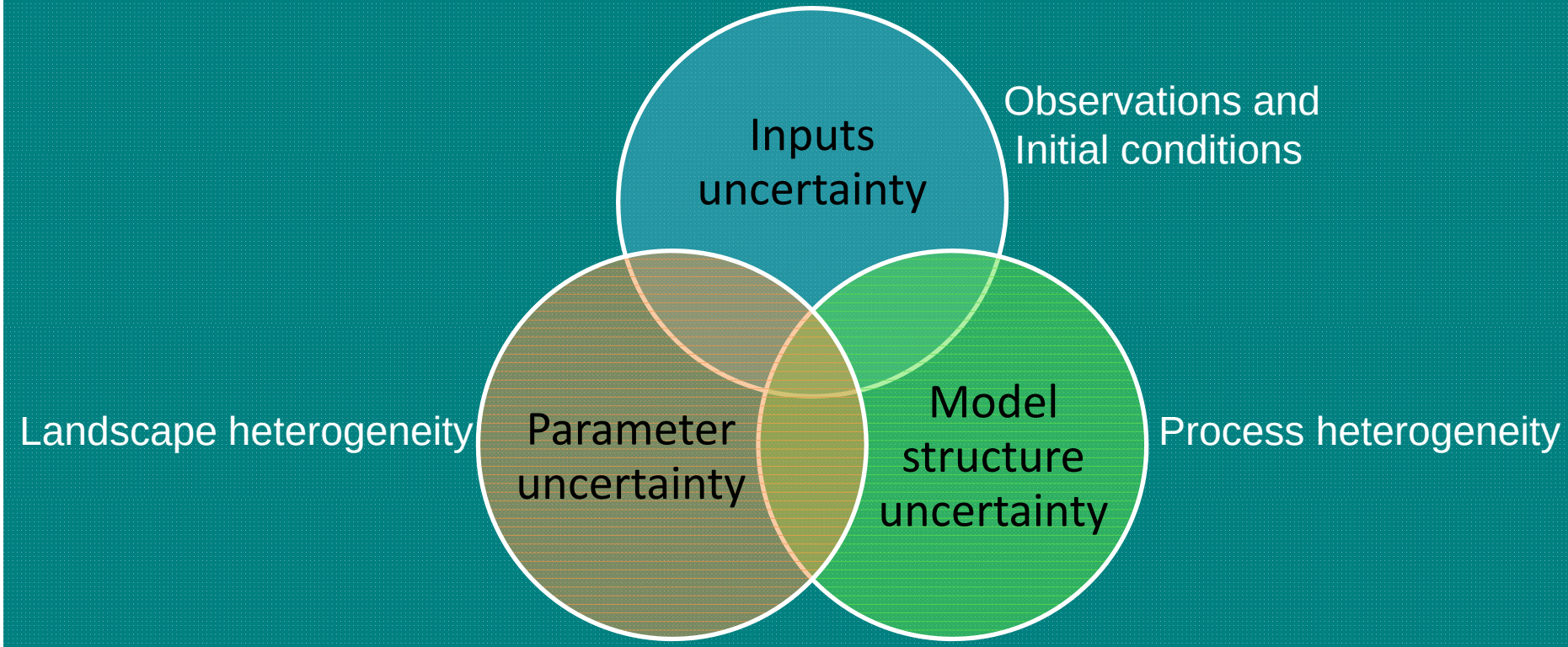
Negative association Melt-SWE



Underestimation of melt duration 4%

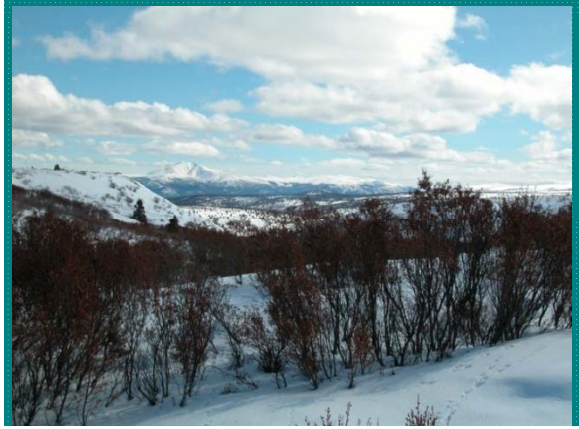
Pomeroy, Essery, and Toth (2004)
A. of Glaciol.,38,195-201.

Predictive uncertainty



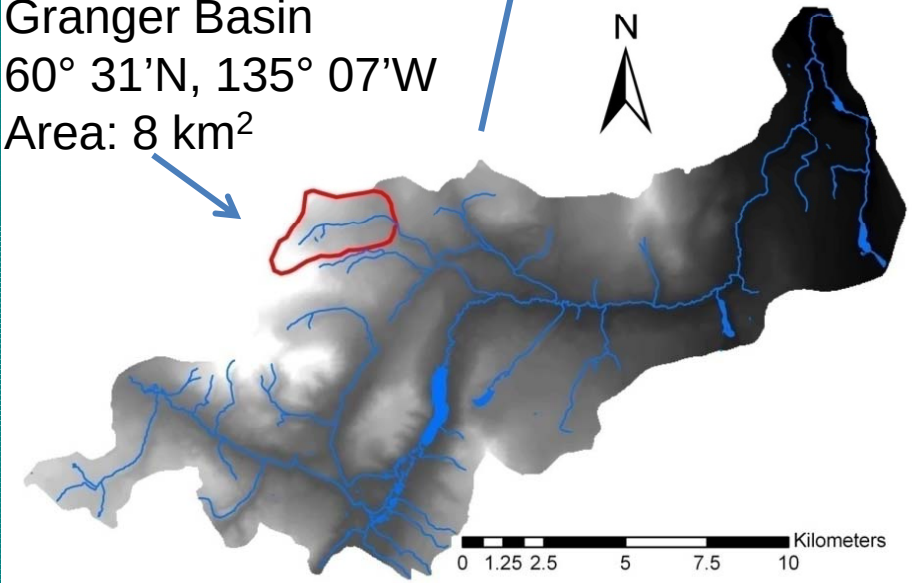
- This situation becomes even more important in cold regions areas due the ungauged nature of arctic and subarctic environments.
- New strategies that combine detailed process understanding with an overall knowledge of the system are needed.

Study area



Wolf Creek Research Basin
60° 31’N, 135° 07’W
Area: 195 km^2

Granger Basin
60° 31’N, 135° 07’W
Area: 8 km^2

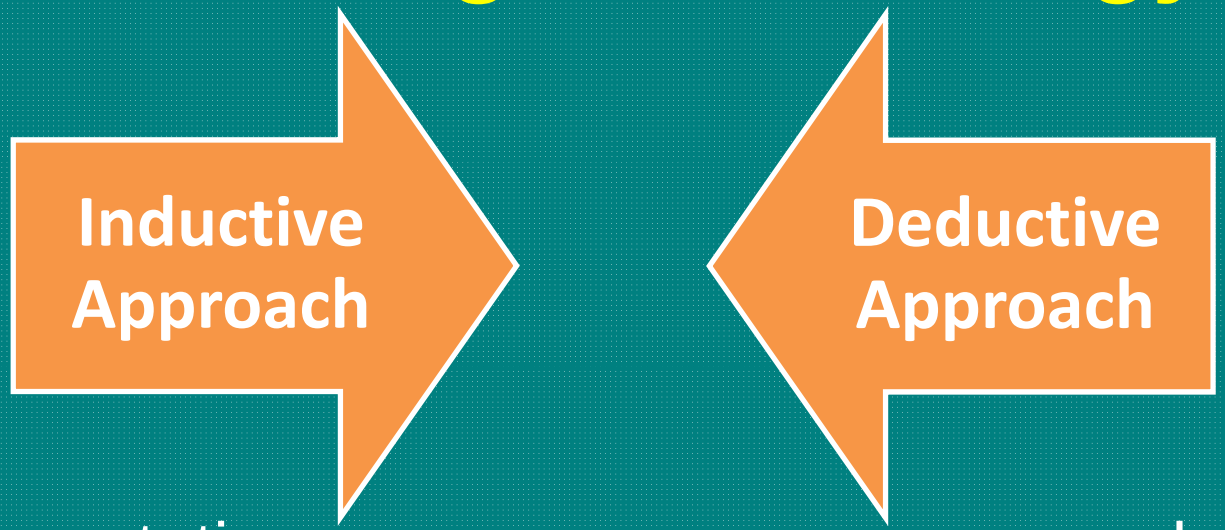


Modelling Objectives

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

1. 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



basin segmentation

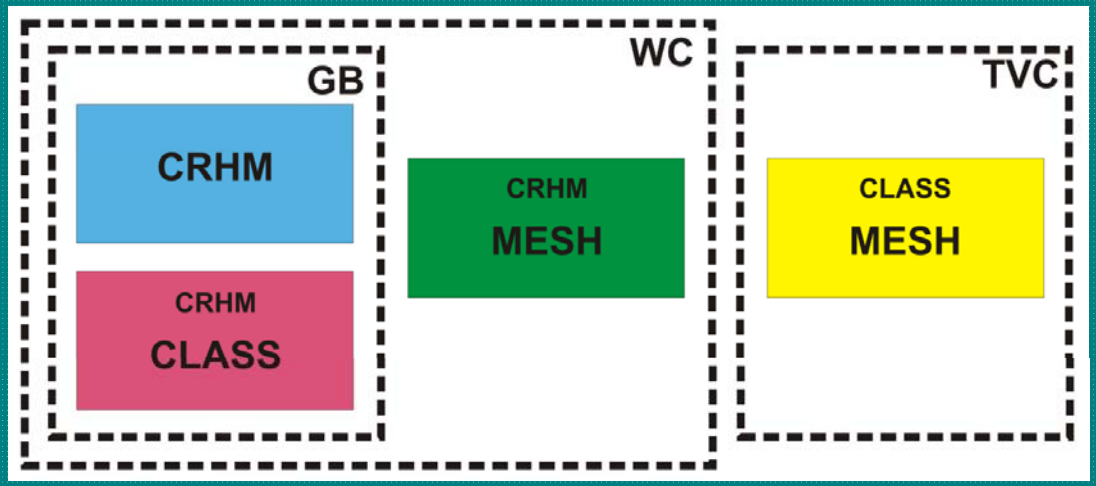
process descriptions

Landscape based
Topography – vegetation

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

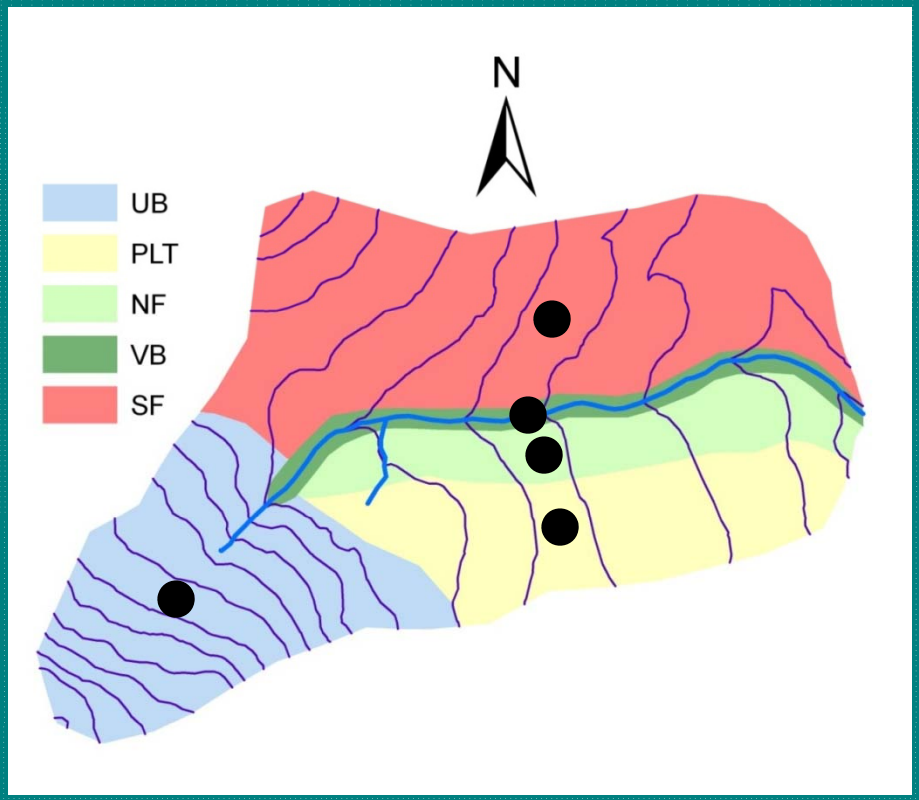
Detail process understanding
In cold regions research basins
(e.g. WC, TVC, prairies)

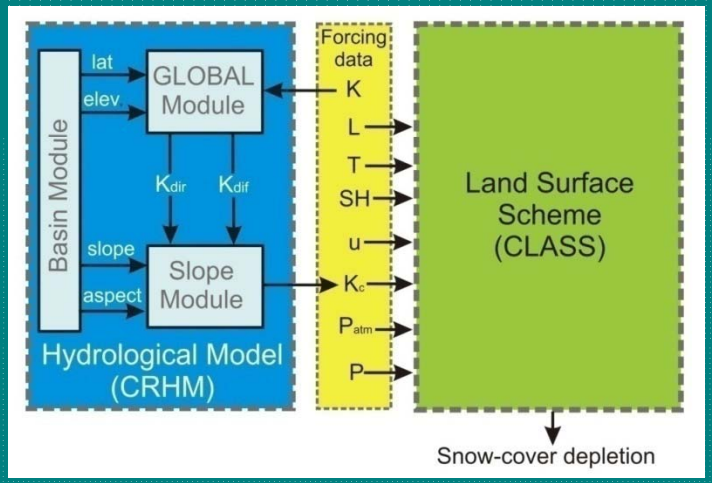
Modelling methodology

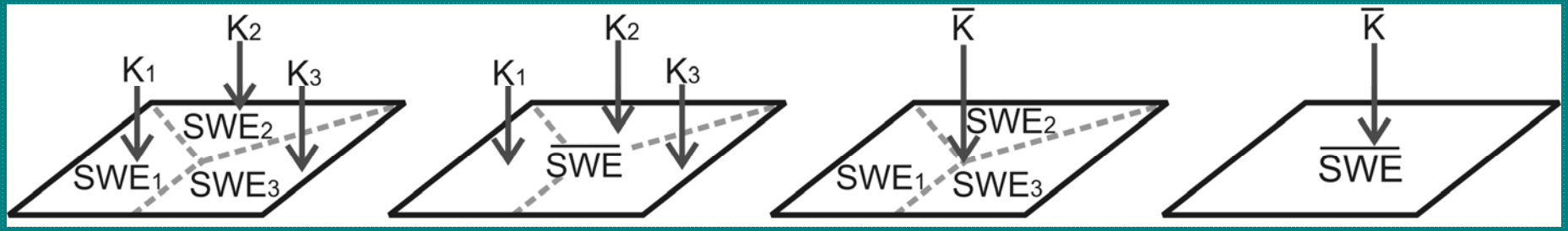


- **Point mode-landscape based** (Granger Basin): **CLASS**
  - Dynamically Dimensioned Search (DDS) global optimisation algorithm →Vegetation parameters governing snowmelt
- **Distributed mode** (Wolf Creek): **MESH modelling system**
  - Using DDS streamflow→ **Hydrology (routing parameters)**
- **Regionalisation**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

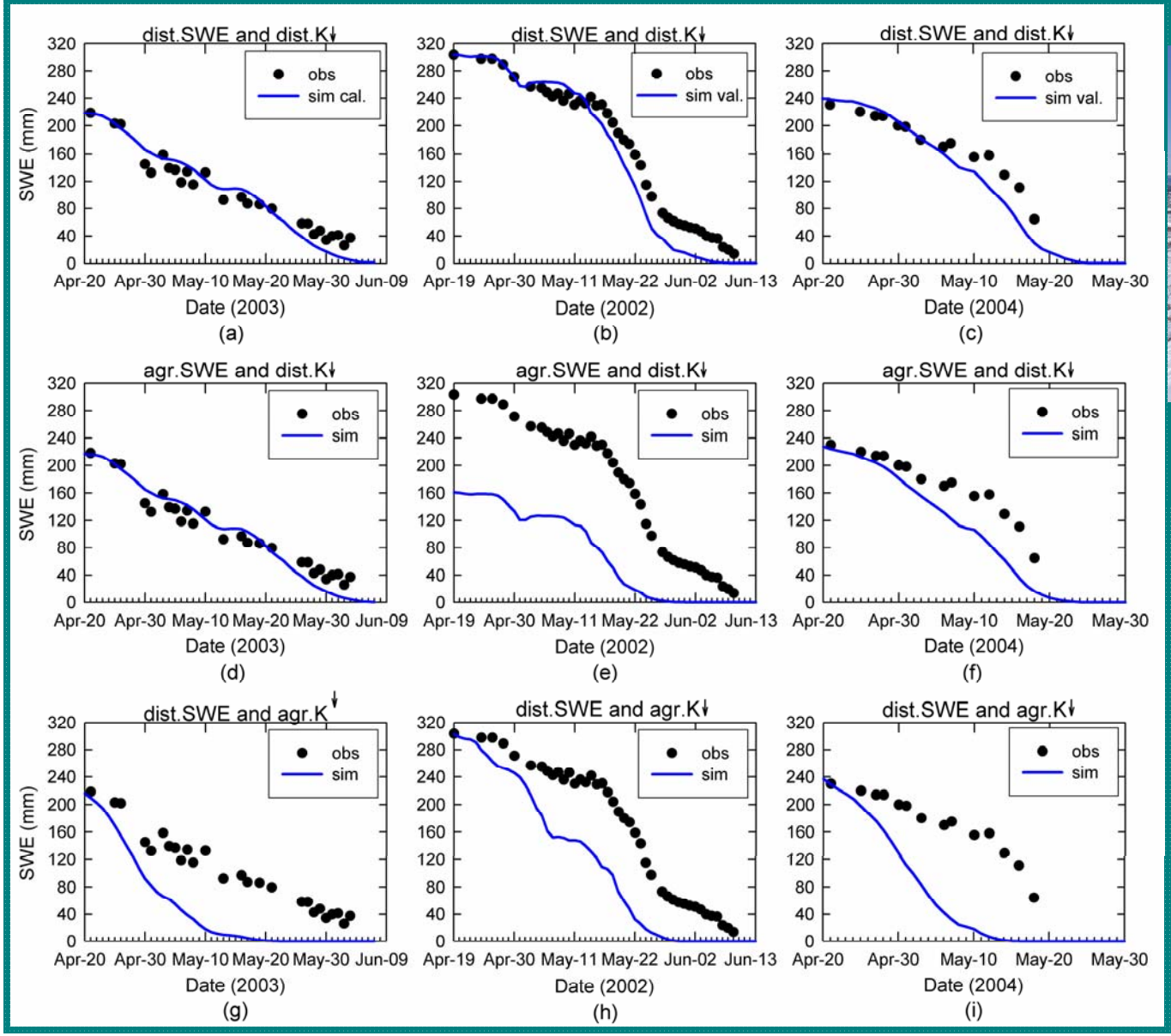
Snow-cover ablation - CLASS

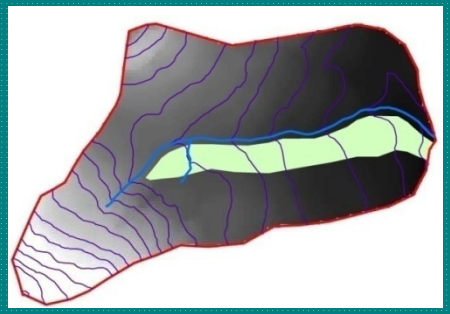




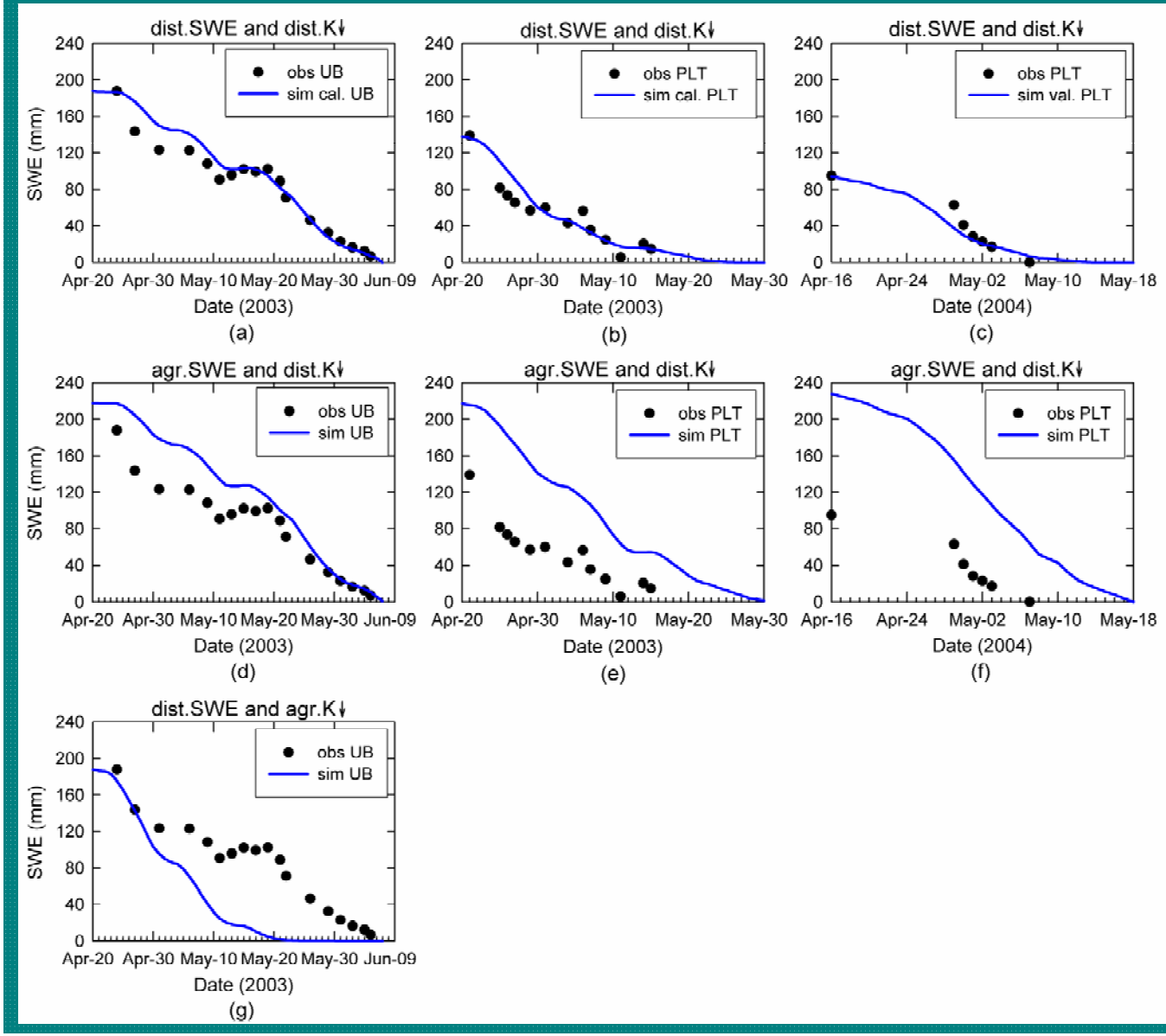


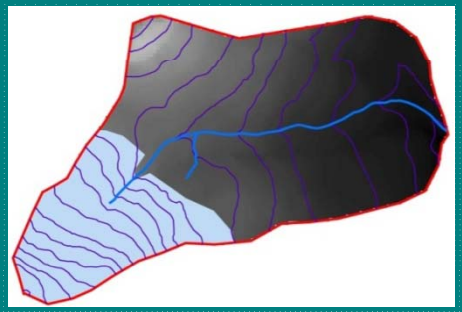
NF - Snow-cover ablation

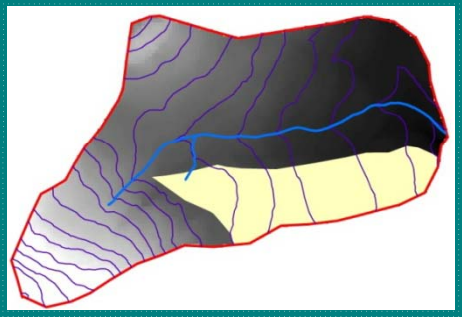




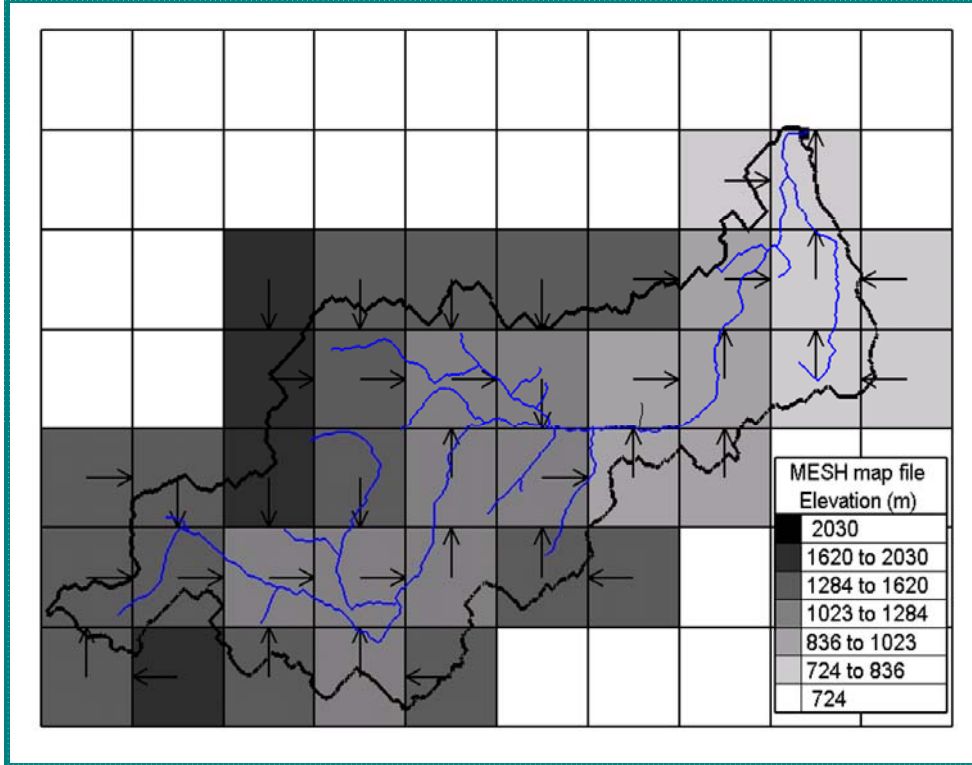
UB & PLT - Snow-cover ablation



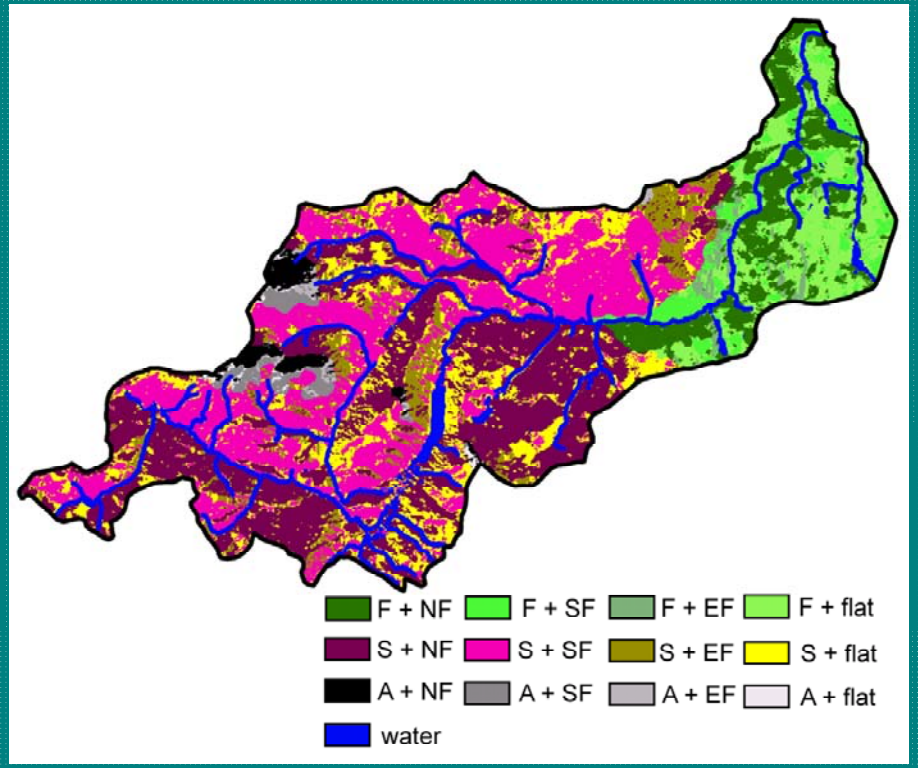




MESH – Spatial representation

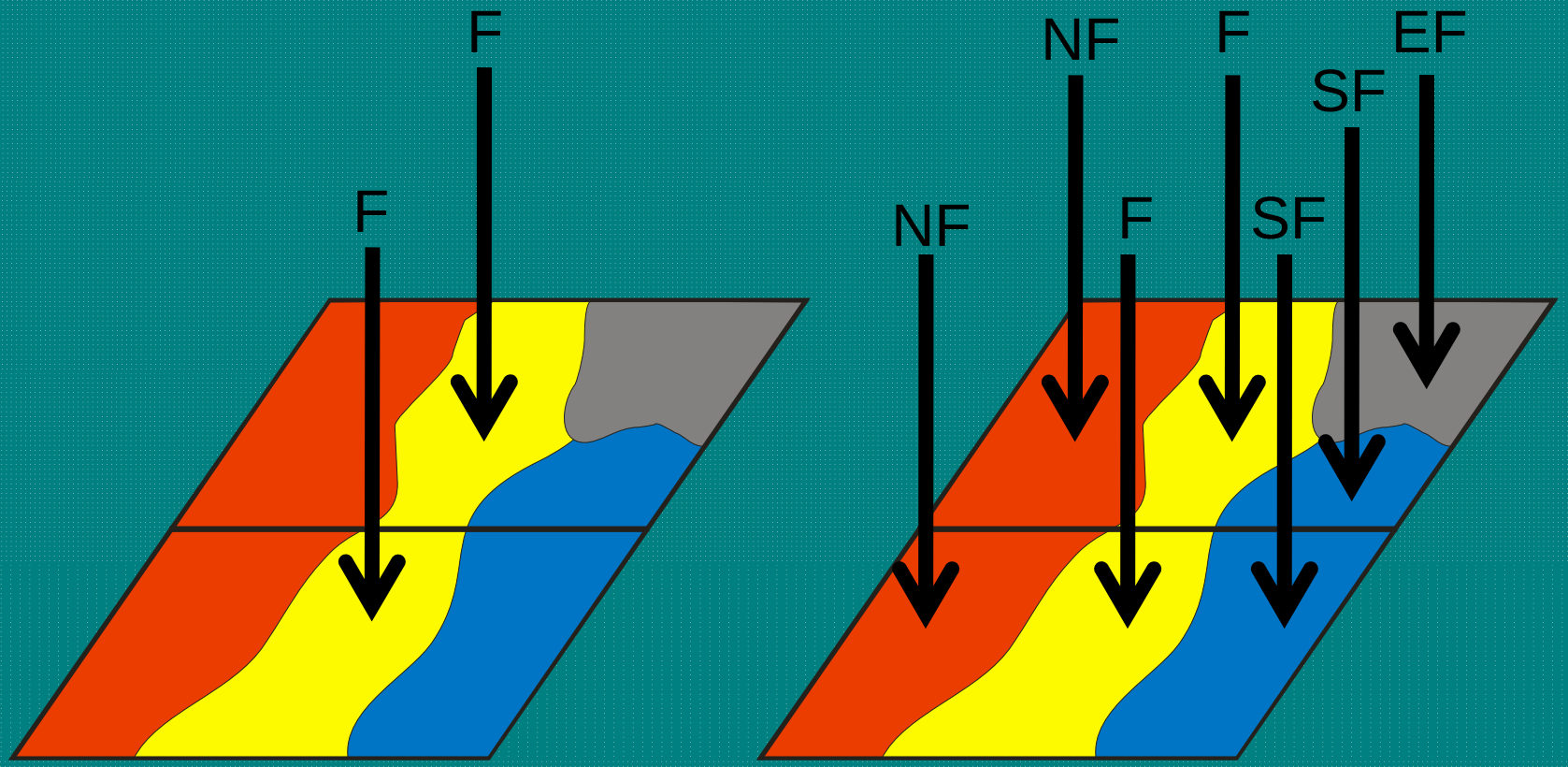


Grid model
spatial discretisation
3 km x 3 km

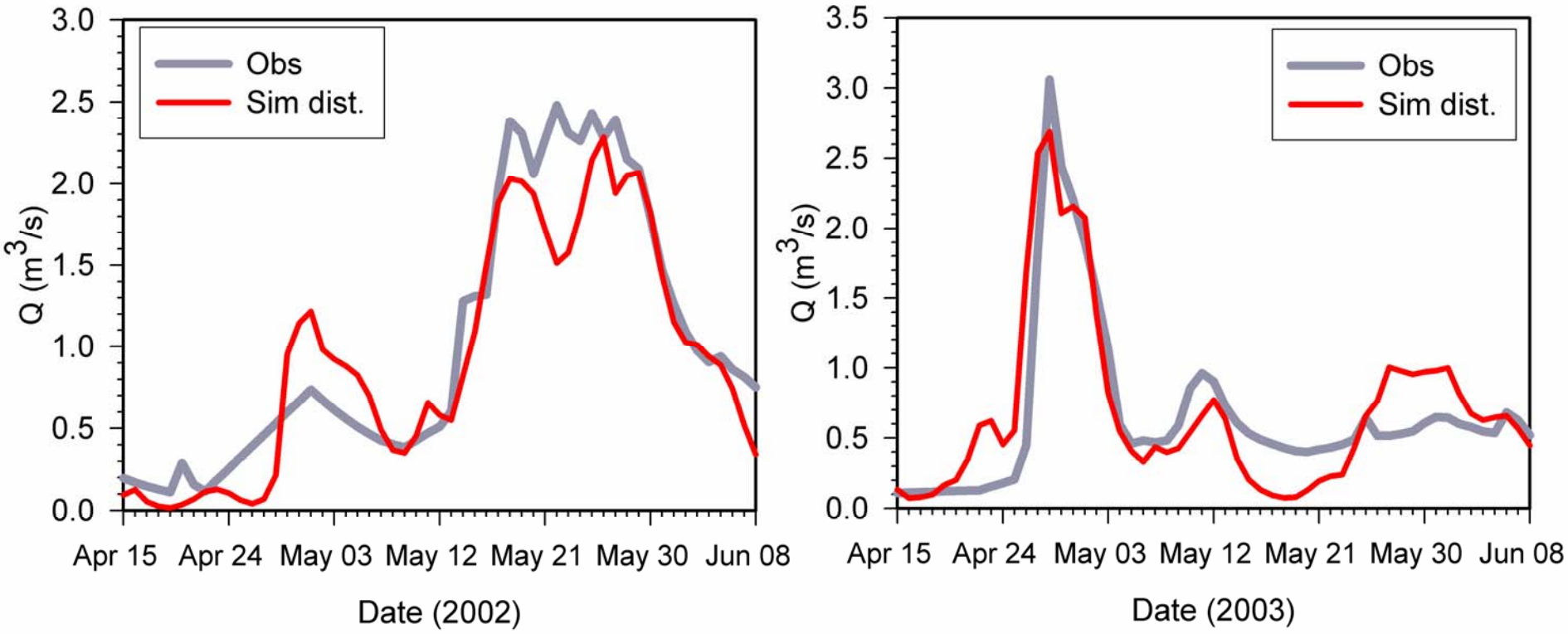


Landscape representation GRU:
topography + land-cover

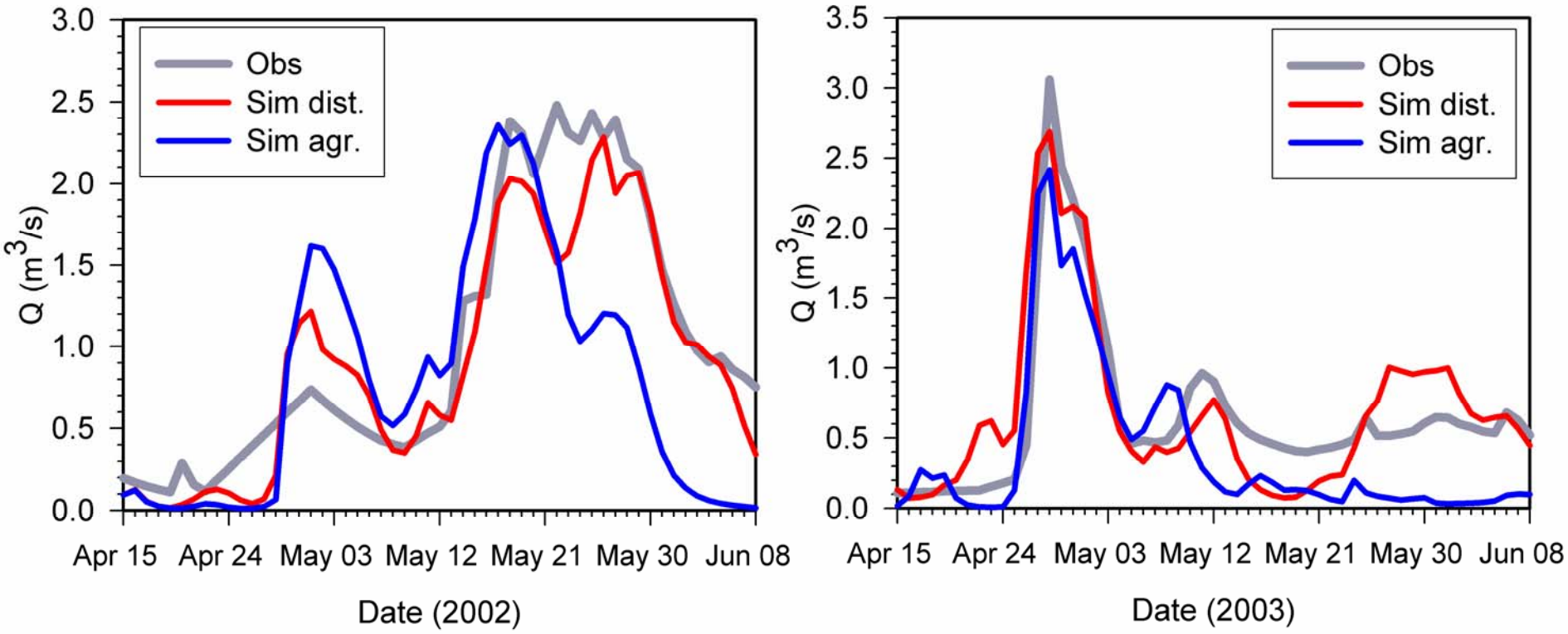
GRU – distributed solar forcing



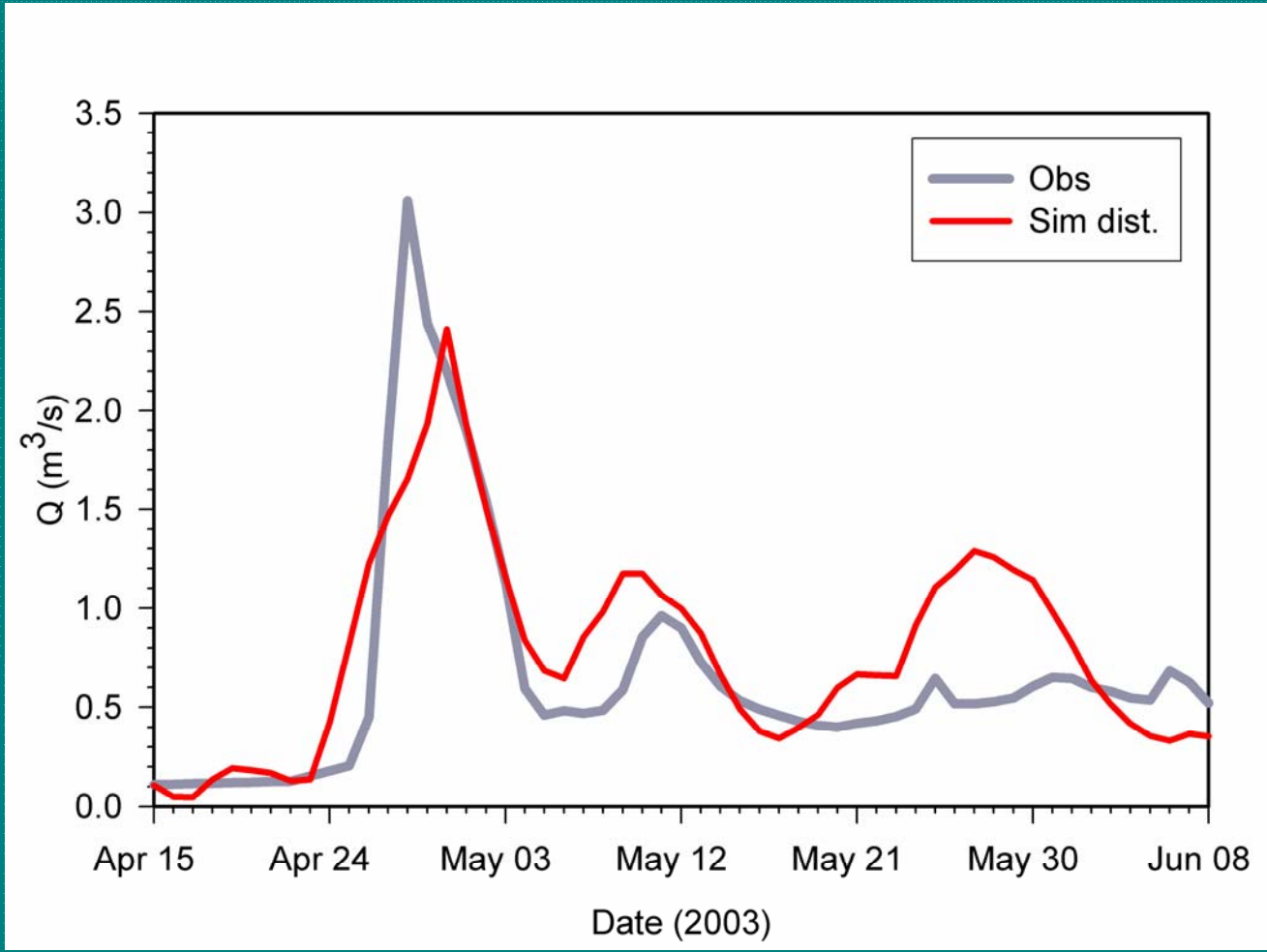
Wolf Creek- discharges (calib.)



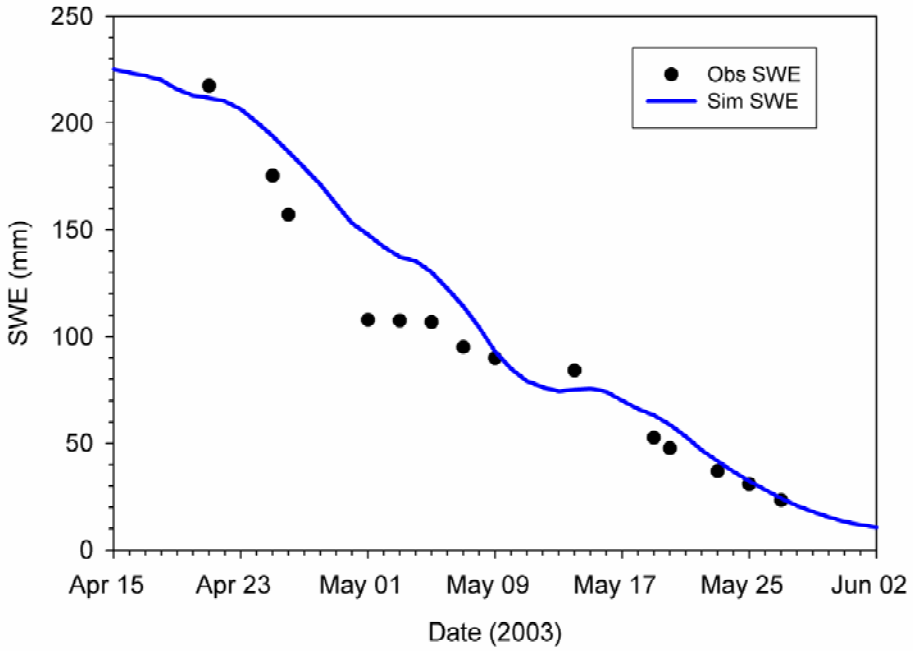
Wolf Creek- discharges (calib.)

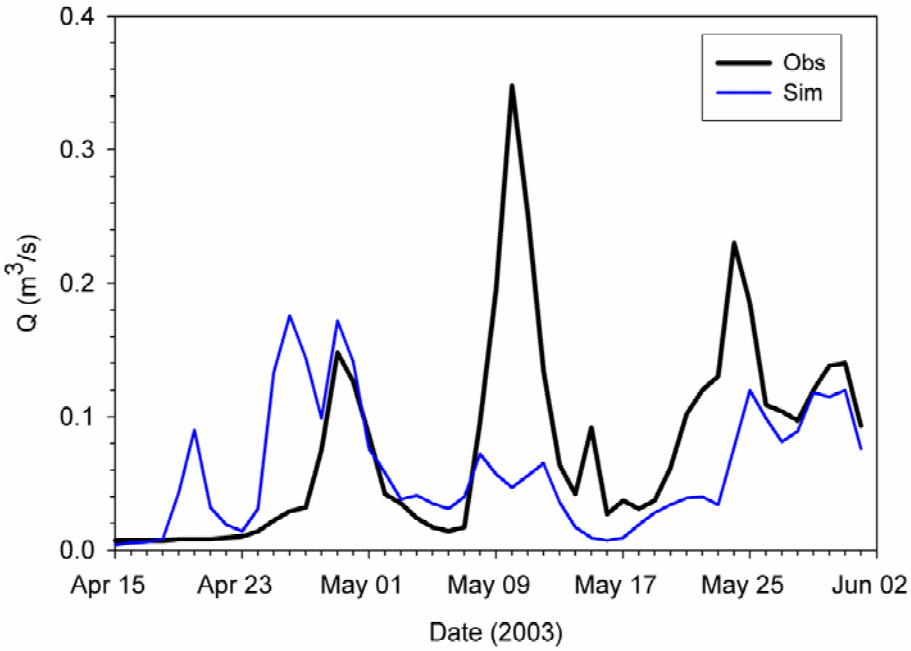


Wolf Creek- discharges (valid.)



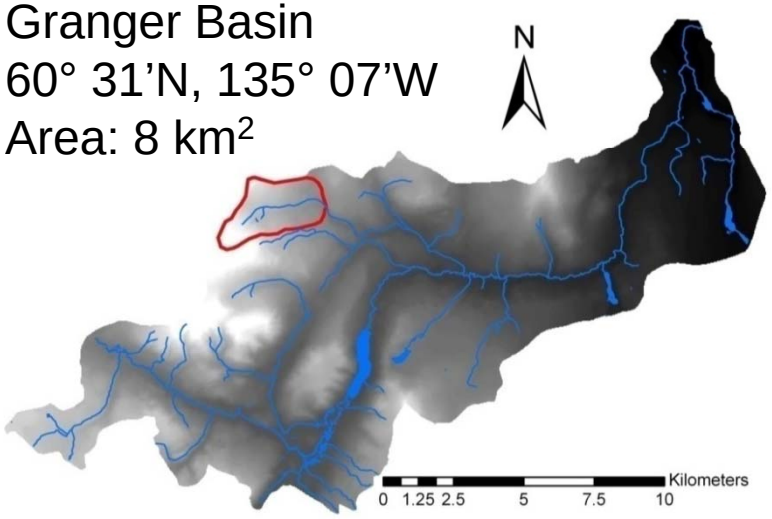
Granger Basin
SWE – streamflow

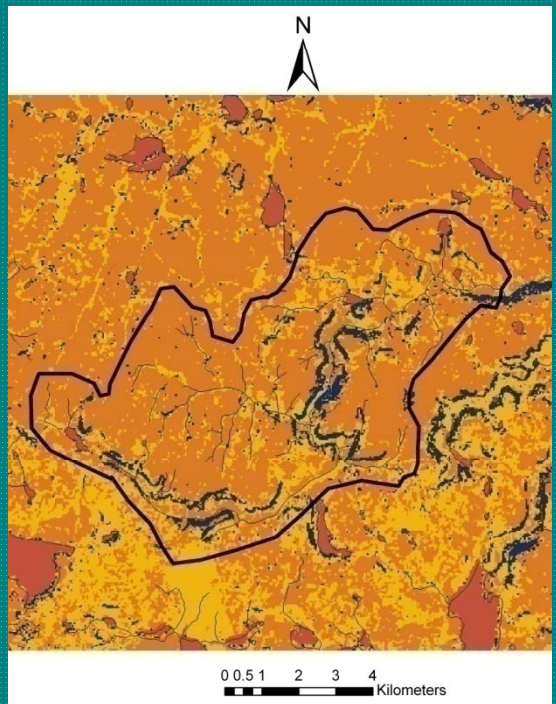




Wolf Creek – Trail Valley Creek

Granger Basin
60° 31'N, 135° 07'W
Area: 8 km^2





TVC Basin
68° 45'N, 133° 30'W
Area: 63 km^2

Model Regionalisation

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

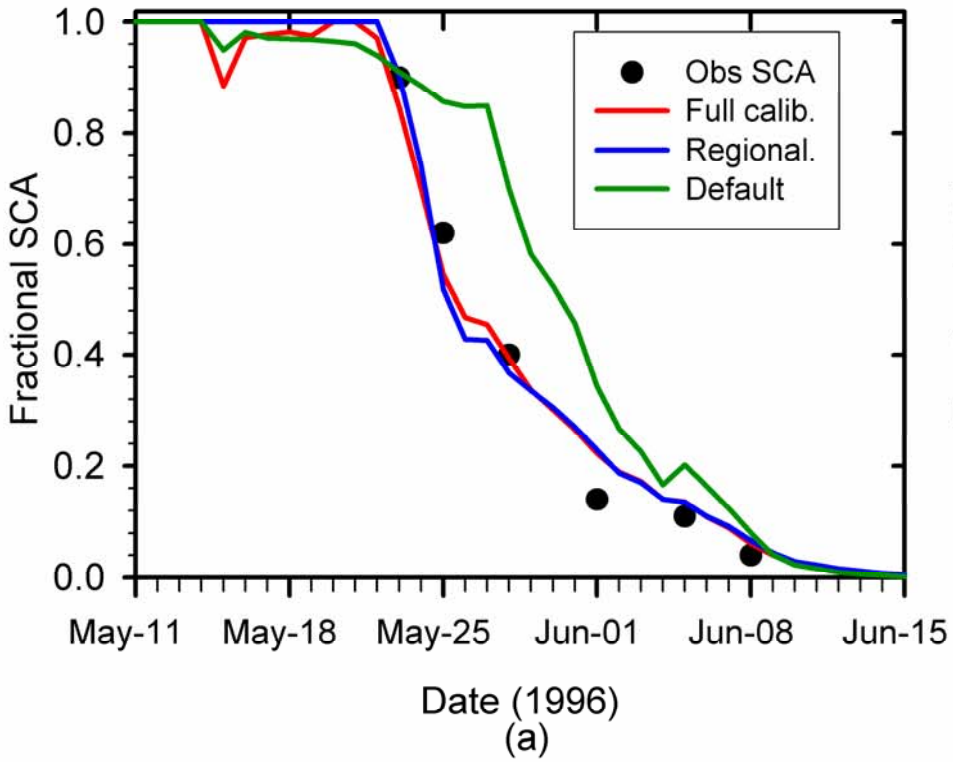
Good for conceptual models – Inappropriate for Physically Based Models

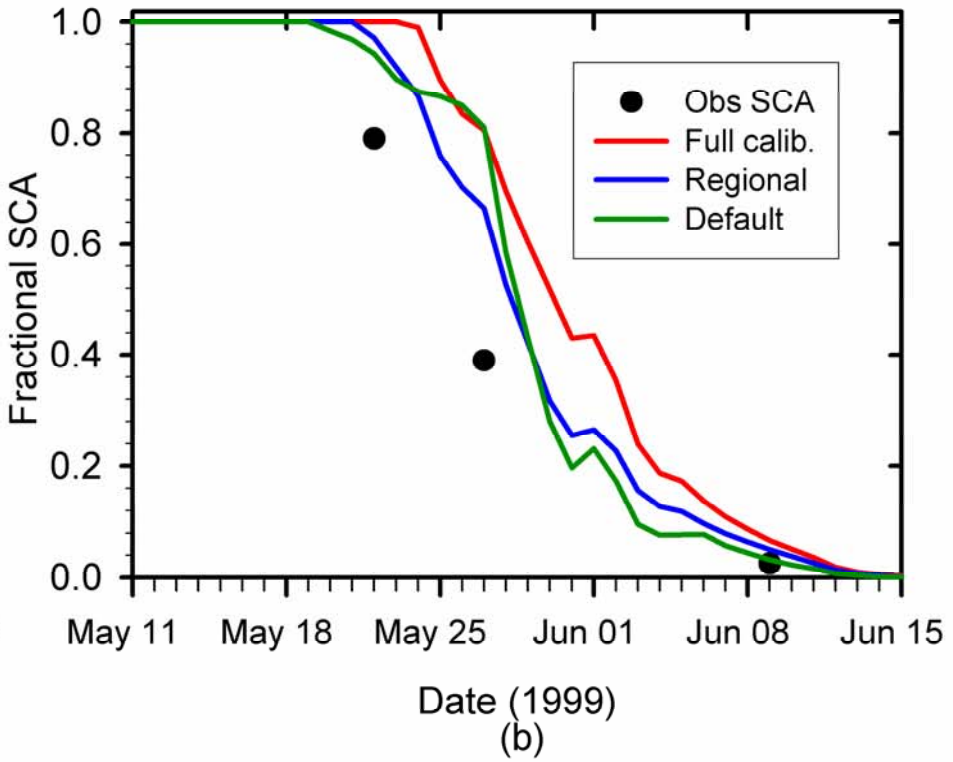
- **Physiographic approach**

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

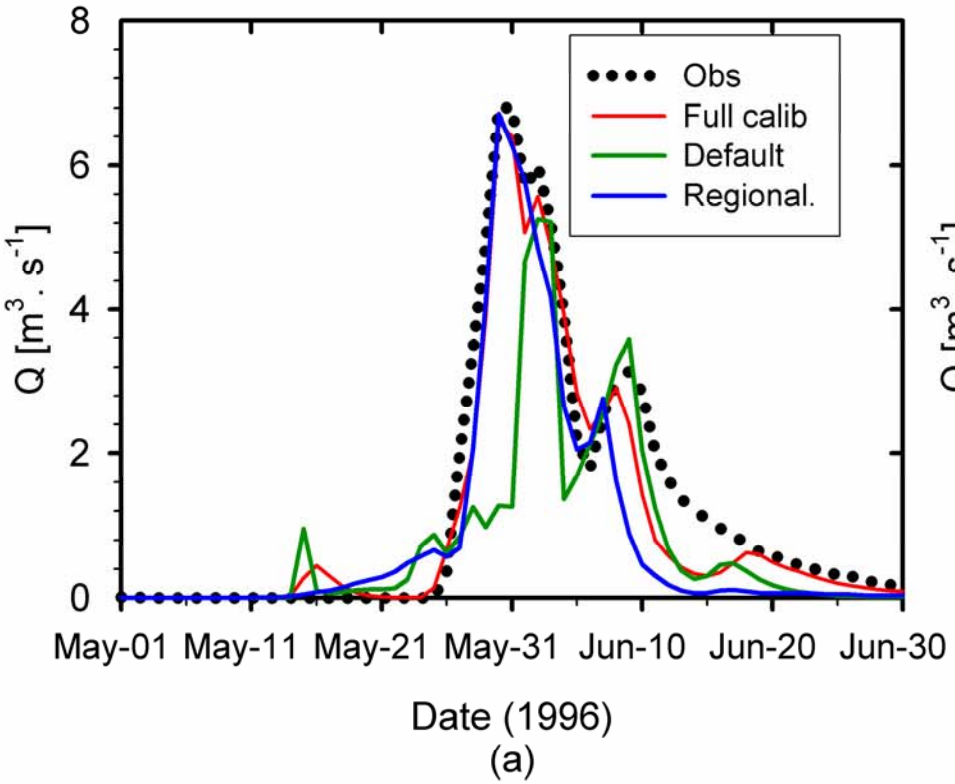
- **Transference of landcover based parameters**

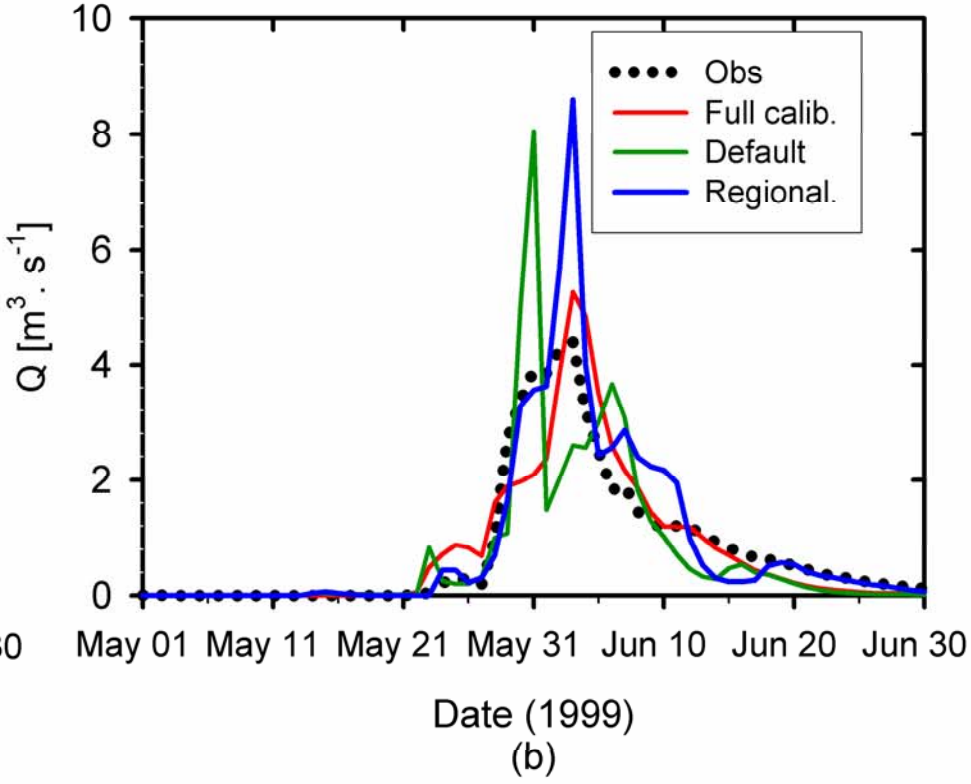
Model Regionalisation TVC - SCA





Model Regionalisation TVC - streamflow





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.


Thank you