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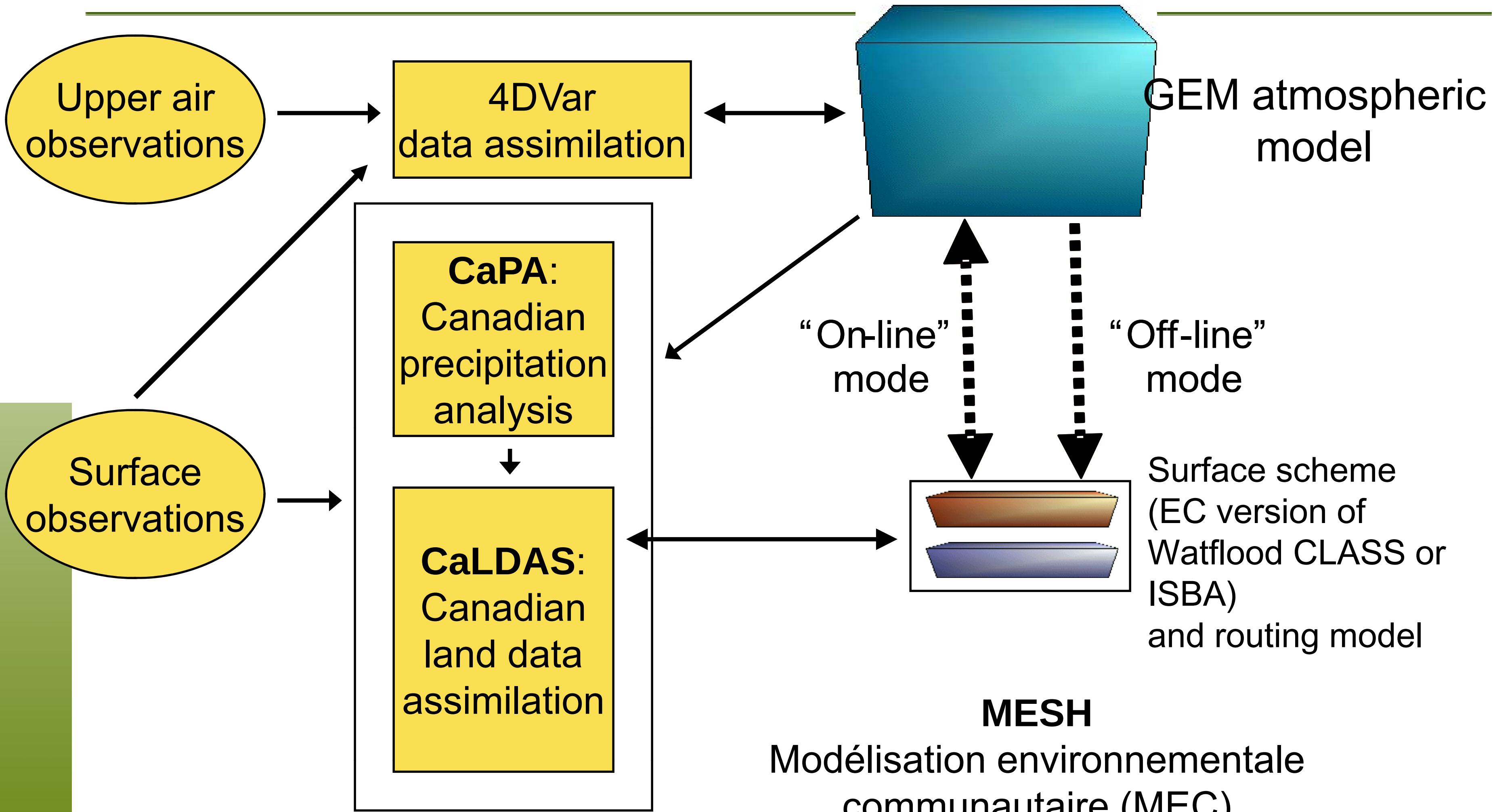
Coupled Hydrological Atmospheric Modelling for IP3

Theme 3 working group

IP3 workshop
Nov 9-10, WLU, Waterloo, Ontario

Environmental Prediction Framework



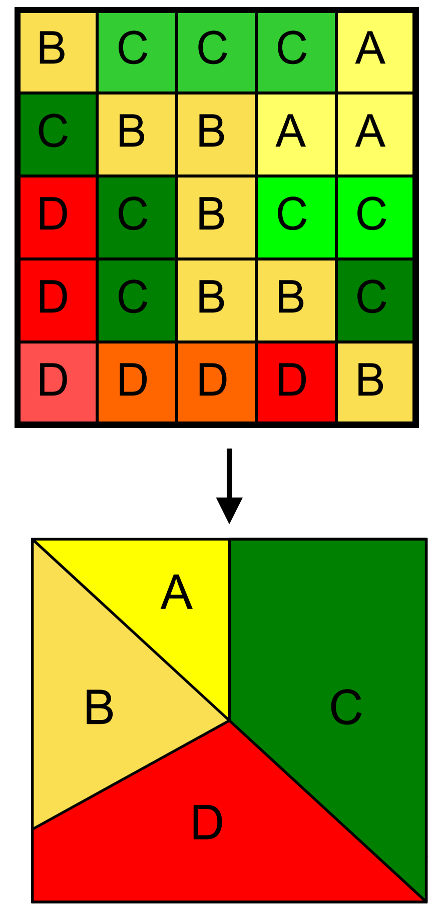
MESH
Modélisation environnementale communautaire (MEC) de la surface et de l'hydrologie

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

- Designed for a regular grid at a 1-15 km resolution
- Each grid divided into grouped response units (GRU or tiles) to deal with subgrid hetereogeneity

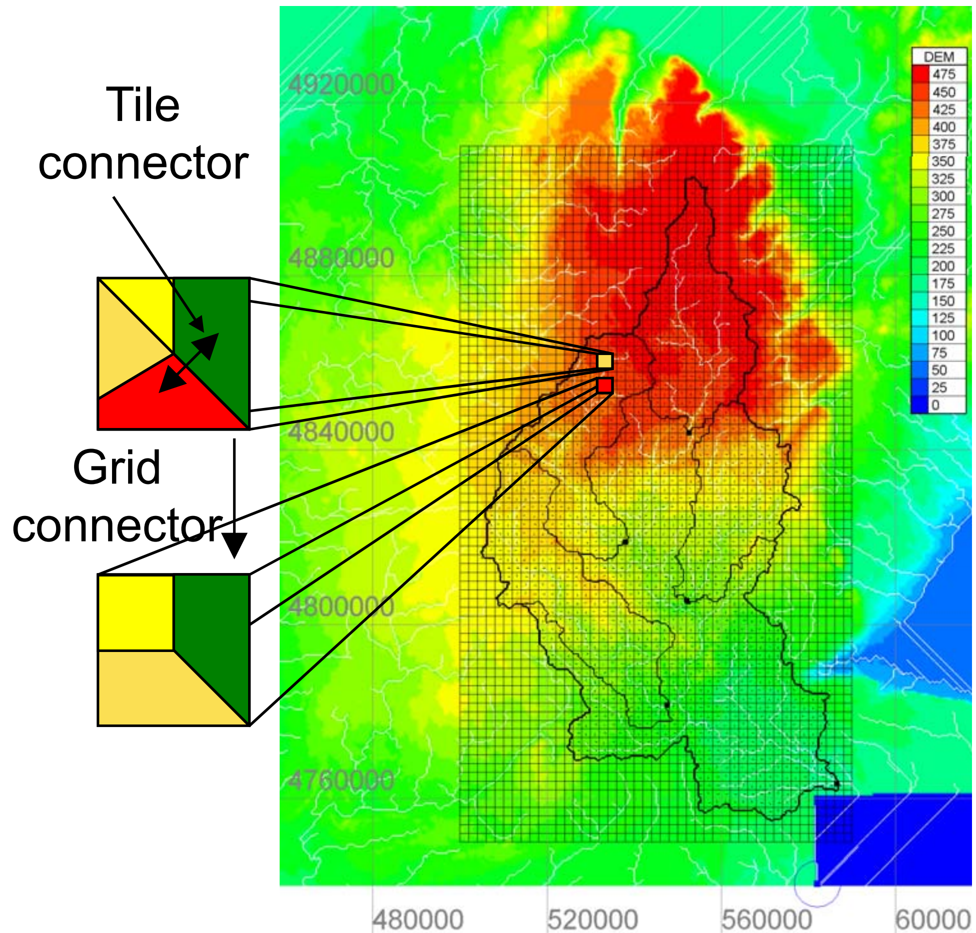
Sub-grid Hetereogeneity (land cover, soil type, slope, aspect, altitude)

A relatively small number of classes are kept, only the % of coverage for each class is kept



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



From Measurements to Models

	Resolution	1 m	100 m	100 m - 2 km	2 - 10 km	10 km -	10 km
			Landscape type	Pattern/tile			
		Tile/HRU	Tile/HRU	Grid/small basin	Multi-grid/medium basin	Multi-grid	
		Point	Hillslope	Sub-basin	Basin	Mesoscale	Regional;
Prediction	Terrestrial Open Water Snow and Ice						
Parametrization	Terrestrial Open Water Snow and Ice						
Process	Terrestrial Open Water Snow and Ice						
MODELS		CHRM	CHRM	MESH CHRM CEOP Hydrology	MESH CHRM CEOP Hydrology	MESH	MESH

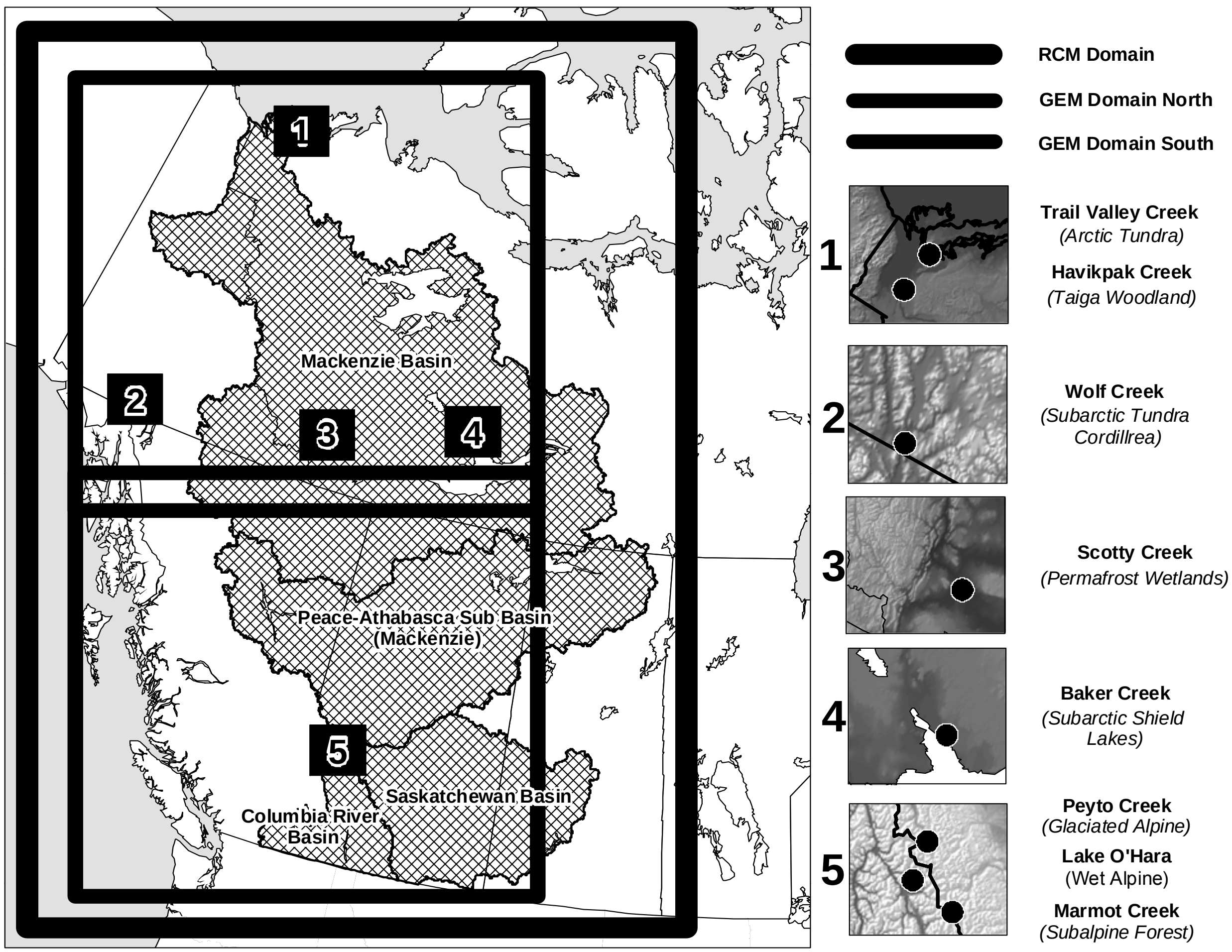
Previous LSS Scaling Methodology

IP3 Scaling Methodology

Quinton CFCAS Study---------------> <----------------------------------MAGS

Modelling and parameterization hierarchy. Previous LSS scaling methodology refers to projects that parameterized and evaluated predictions of processes at a point and then applied directly to regional scales. IP3 scaling methodology involves step-wise transfer of upscaled processes to basin-scale parameterizations and then to regional scales

Scale matters



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Advancements

- Establishing MESH domains at the basin scale
  - Partnerships for most research basins have formed.
  - Single Grid version of CLASS for each basin has been set-up by U of W.
    - Soulis and Seglenieks
  - Software Engineering and repository established at HAL lab
    - Davison
  - DDS working with CLASS and MESH
    - Tolson

Calibration of a Land Surface Hydrology Scheme in Arctic Environments

Pablo Dornes[1], Bruce Davison[2], Alain Pietroniro[2]
Bryan Tolson[3], Ric Soulis[3], Philip Marsh[2], and John Pomeroy[1]

1 Centre for Hydrology, University of Saskatchewan, Saskatoon, SK, Canada
2 Environment Canada, Saskatoon, SK, Canada
3 University of Waterloo, ON, Canada

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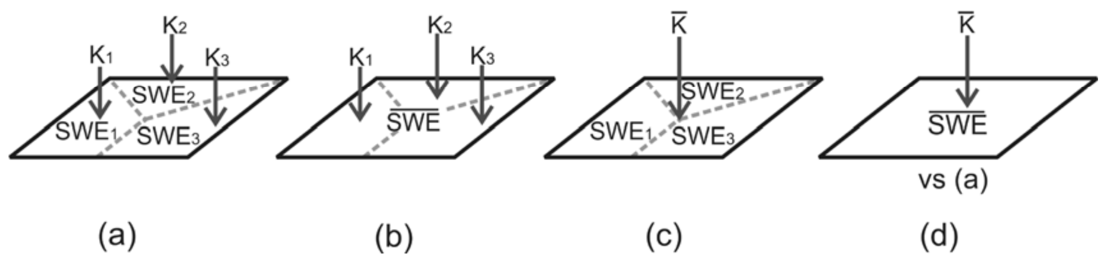
Objectives

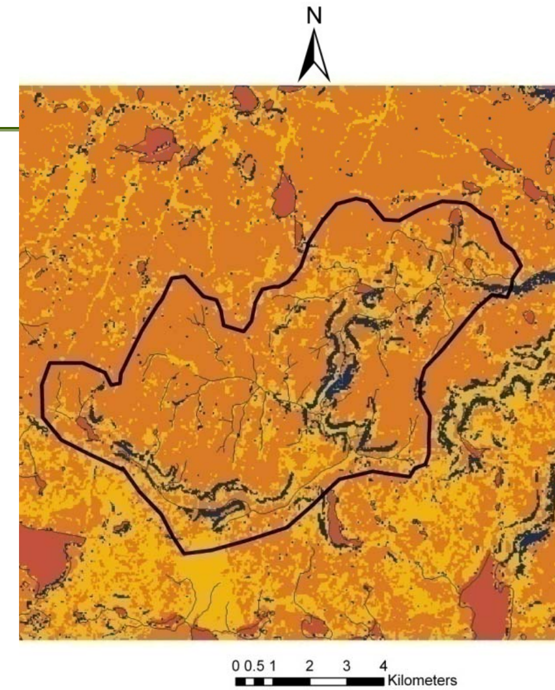
To parameterise a LS-Hydrological model,A stepwise procedure is applied:

1. Calibration of a LSS in a point mode using a single-objective function (snow water equivalent-SWE). Examination of the effects of including an explicit representation in a LSS of:
   a) Fully distributed (calibrated)
   b) Initial conditions,
   c) Forcing data.
   d) all

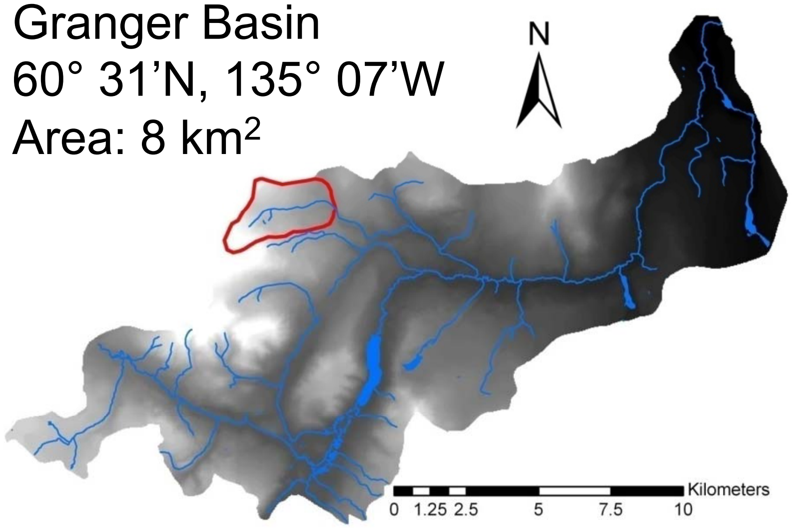


2. Calibration of a LS-Hydrological model using a multi-objective function (streamflow and snow cover area-SCA) by keeping the vegetation parameters calibrated in point 1.

Wolf Creek – Trail Valley Creek

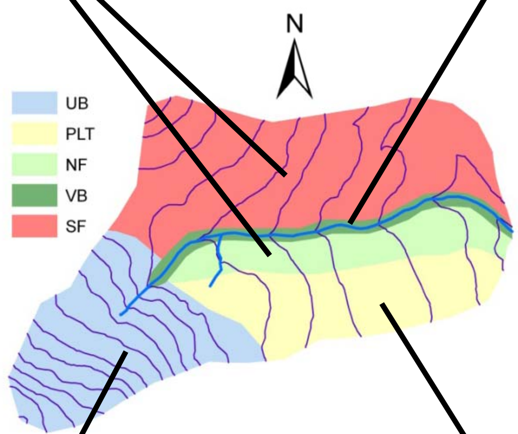


Granger Basin
60° 31'N, 135° 07'W
Area: 8 km^2



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

Landscape Heterogeneity



Modelling strategy
LSS

The Canadian Land Surface Scheme (CLASS 3.3)

- Calibration 2003

Objective function: Snow Water Equivalent (SWE)

Dynamically Dimensioned Search (DDS) global optimisation algorithm (Tolson and Shoemaker WRR 2007)

25 parameters (12 for shrubs, 12 for grass, and 1 for snow-cover depletion, SCD) that govern snowmelt

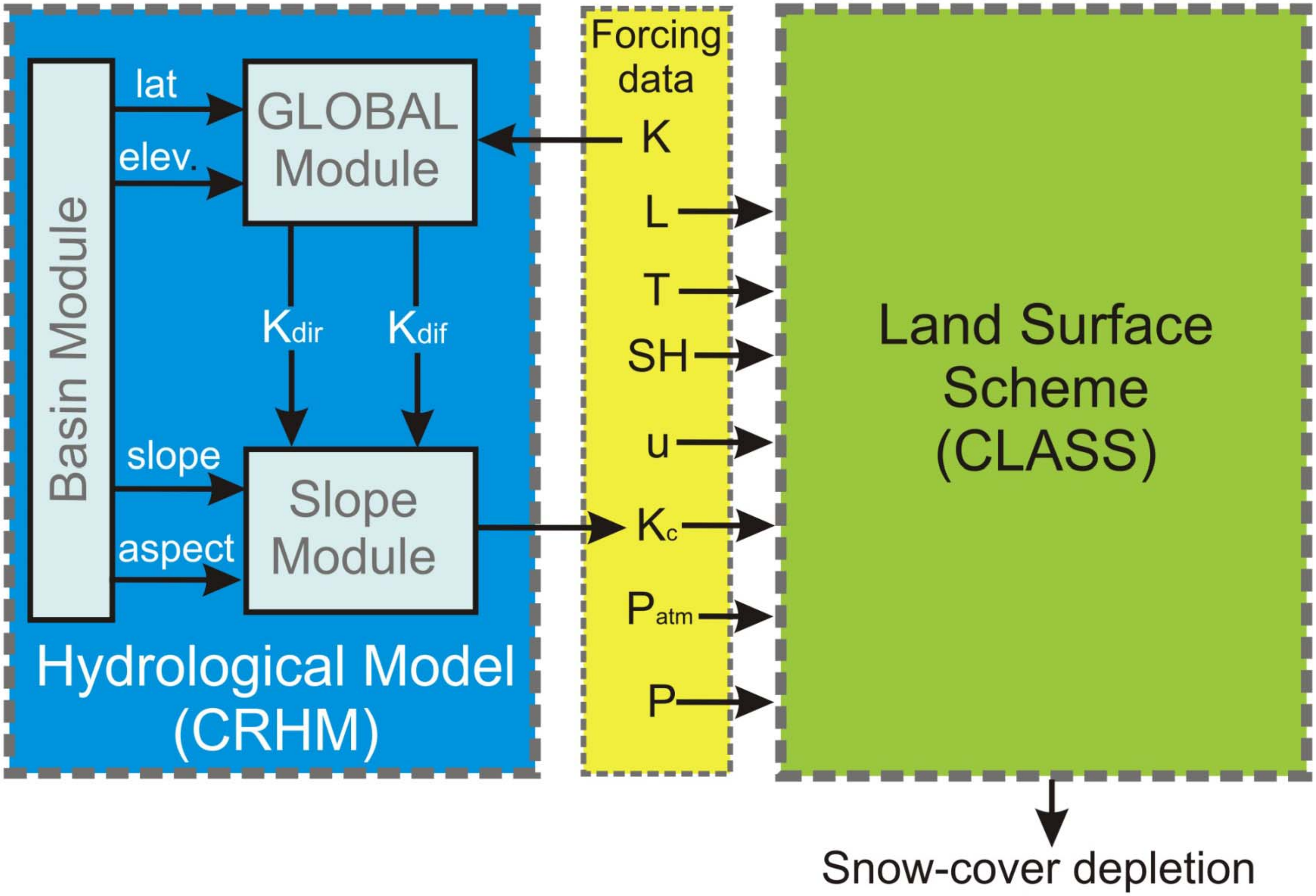
- Validation 2002 and 2004

- Effects of initial conditions were analysed from extensive field observations whereas forcing data effects were evaluated using the Cold Region Hydrological Model (CRHM) as a prepossessing data for CLASS.

Parameter	PLT	NF
	Open tundra	Shrub tundra
Max. LAI (LAMX)	0.53 (0.5, 2)	2.81 (2, 3)
Min. LAI (LAMN)	0.28 (0.5, 3)	0.99 (0.4, 1)
LN roughness length (LNZ0) [m]	-4.09 (-4.8, -3.5)	-2.42 (-3.7, -1.8)
Visible albedo (ALVC)	0.183 (0.02, 0.2)	0.087 (0.03, 0.2)
Near-infrared albedo (ALIC)	0.424 (0.2, 0.4)	0.464 (0.3, 0.5)
Biomass Den. (CMAS) [$Kg \cdot m^{-2}$]	0.11 (0.05, 0.35)	6.13 (6, 10)
Min. stomatal resist. (RSMN)	251.5 (50, 300)	51.9 (50, 300)
Coef. stomata resp. to light (QA50) [$W \cdot m^{-2}$]	46.1 (20, 60)	21.1 (20, 60)
Coef. stomatal resist. to VP deficit (VPDA)	1.31 (0.2, 1.5)	1.08 (0.2, 1.5)
Coef. stomatal resist. to VP deficit (VPDB)	0.61 (0.2, 1.5)	0.93 (0.2, 1.5)
Coef. stomatal resist. to soil WS (PSGA)	146.7 (50, 150)	93.5 (50, 150)
Coef. stomatal resist. to soil WS (PSGB)	4.92 (1-10)	1.09 (1-10)
Lower snow depth limit for 100% SCA (D_{100}) [m]	0.42 (0.05-0.5)	0.81 (0.05-1)

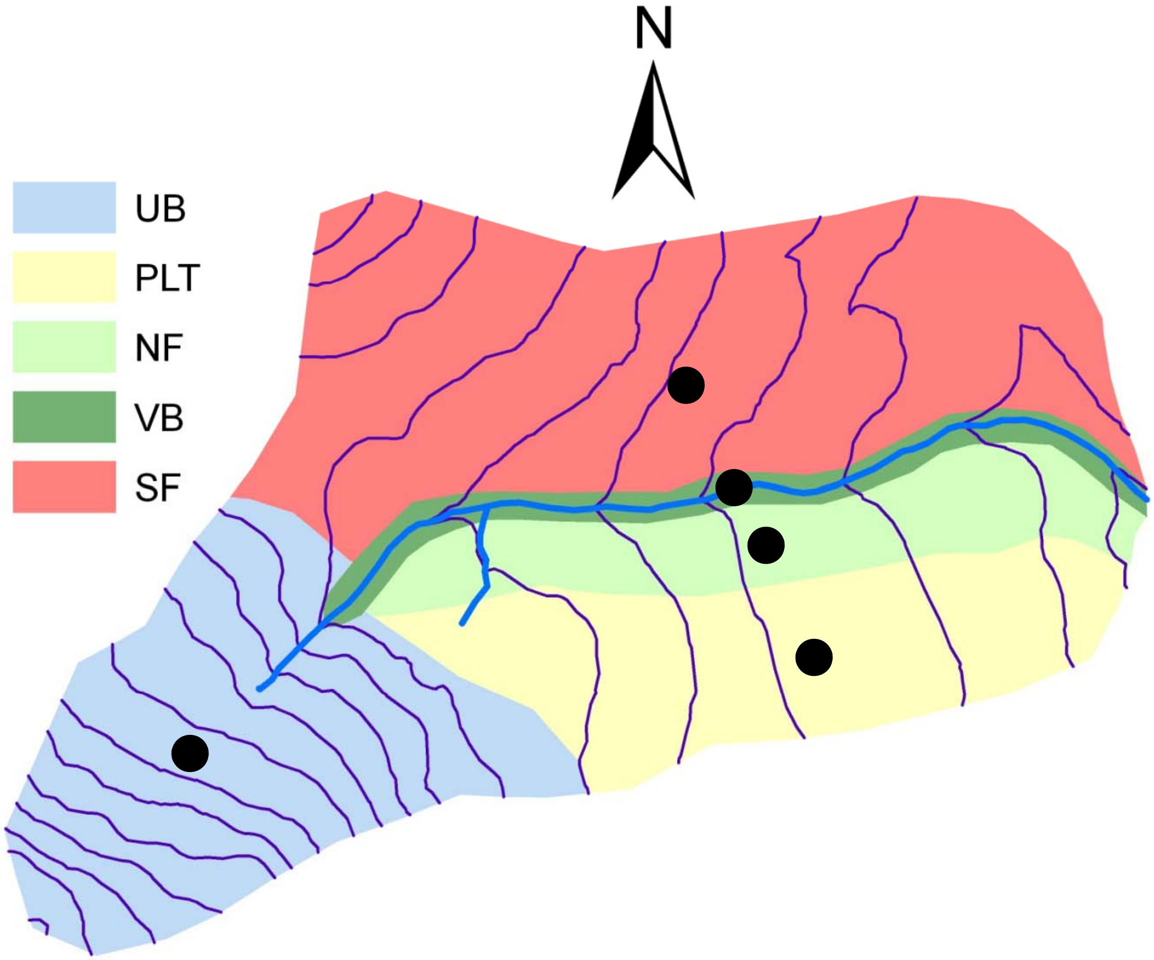
Modelling strategy

CRHM – Short wave correction

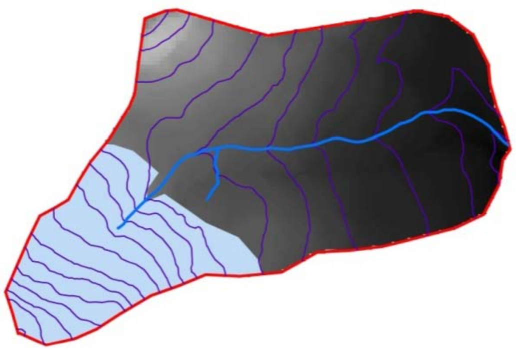


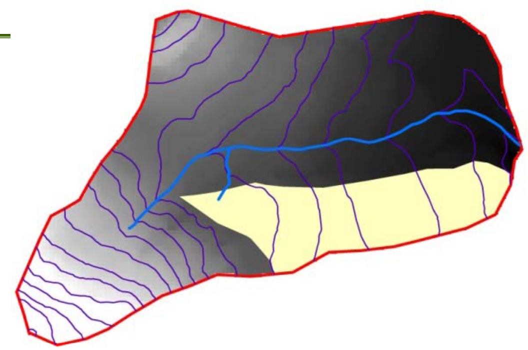
Modelling strategy

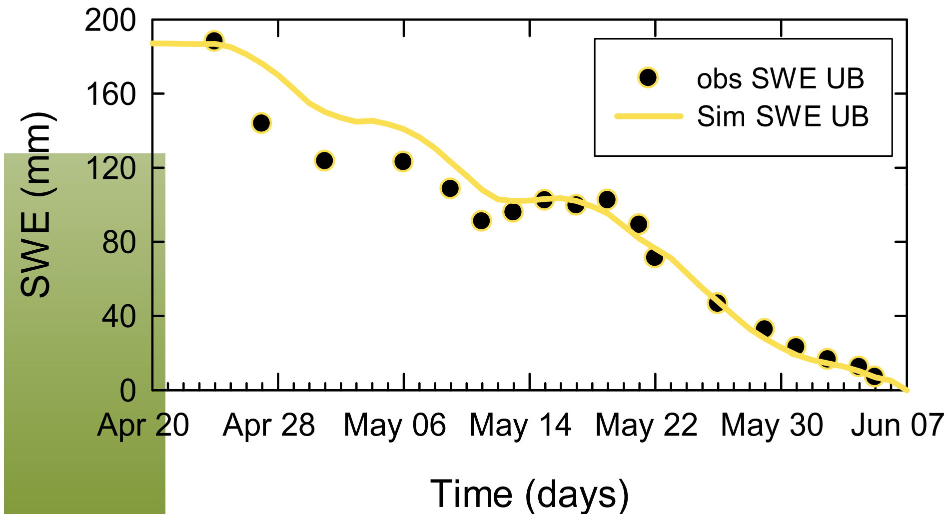
CLASS – Point mode

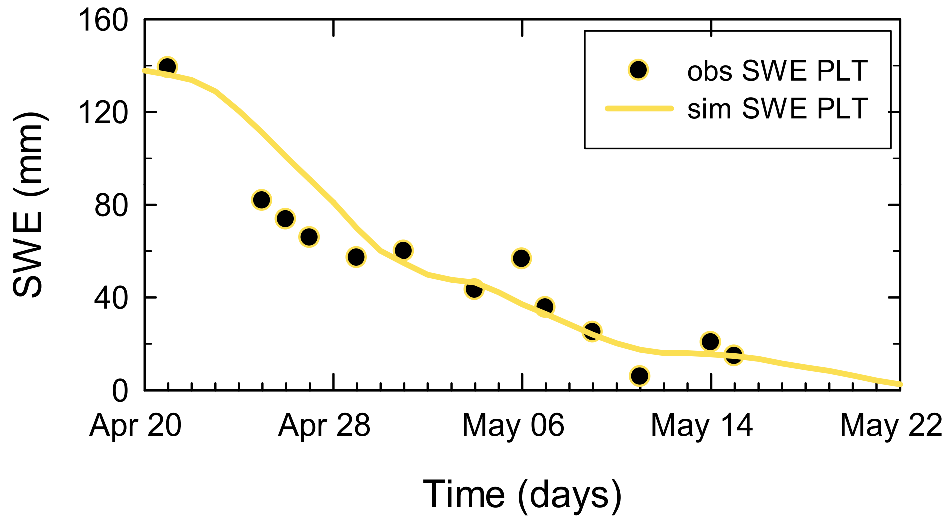


SWE - Calibration period - 2003

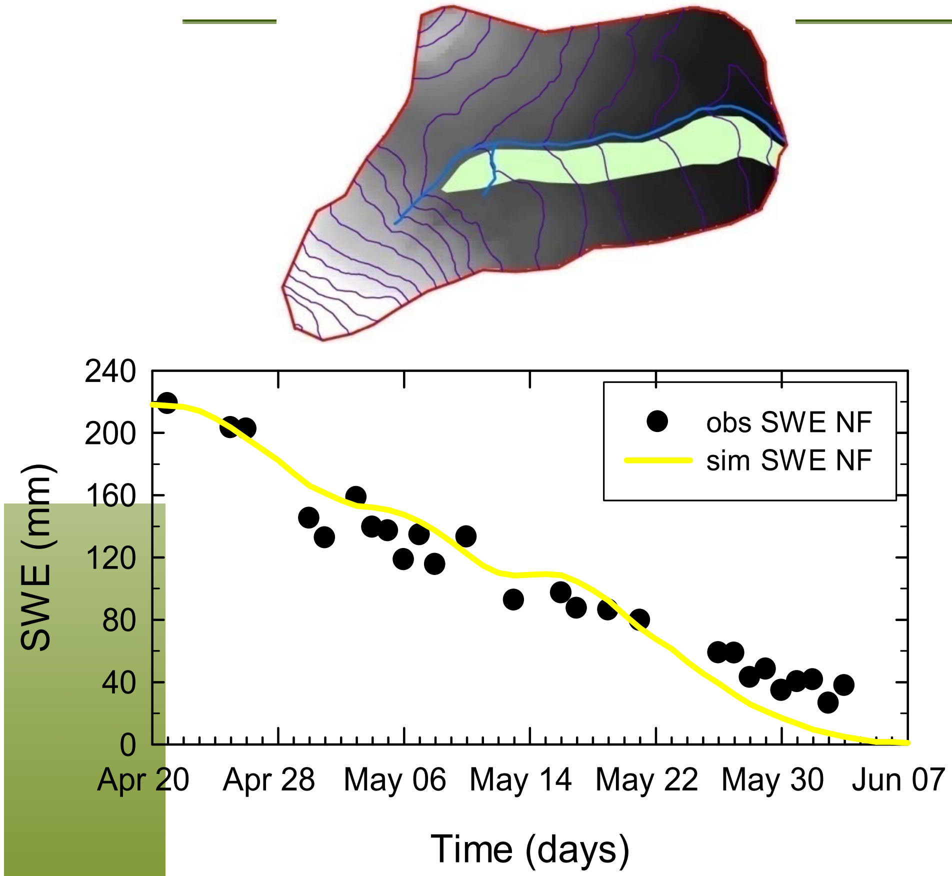


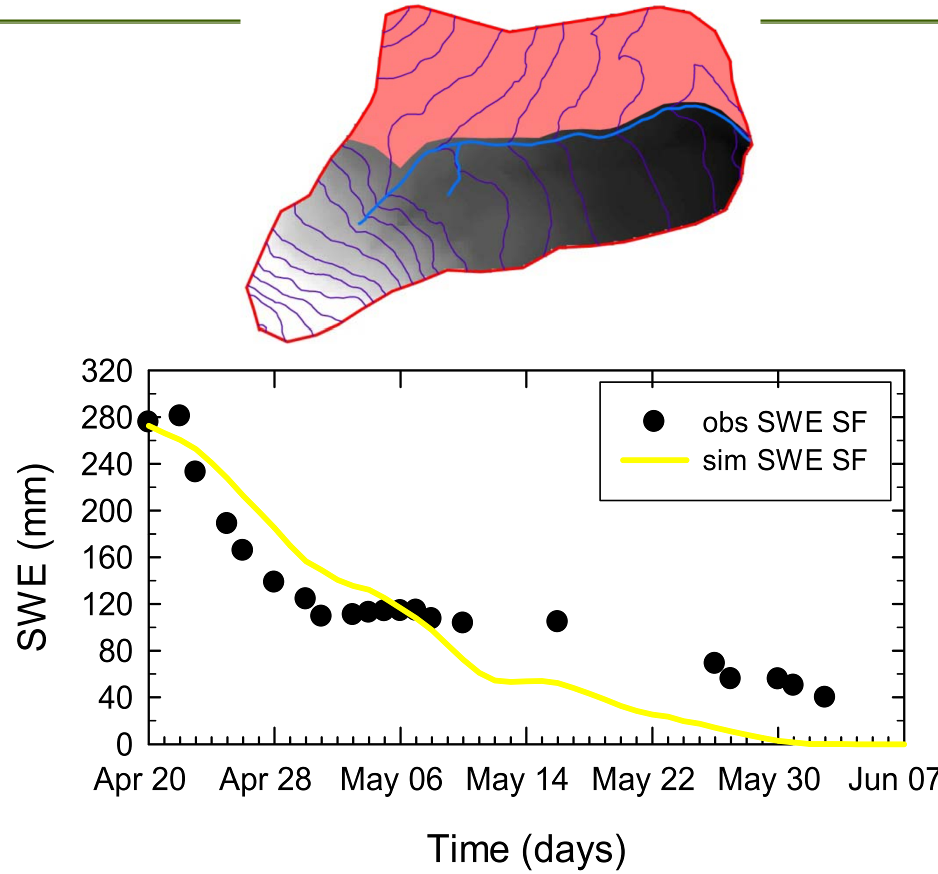




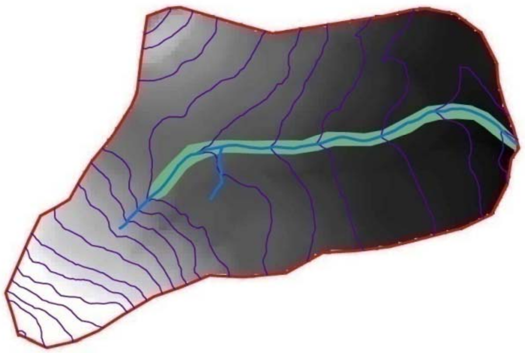


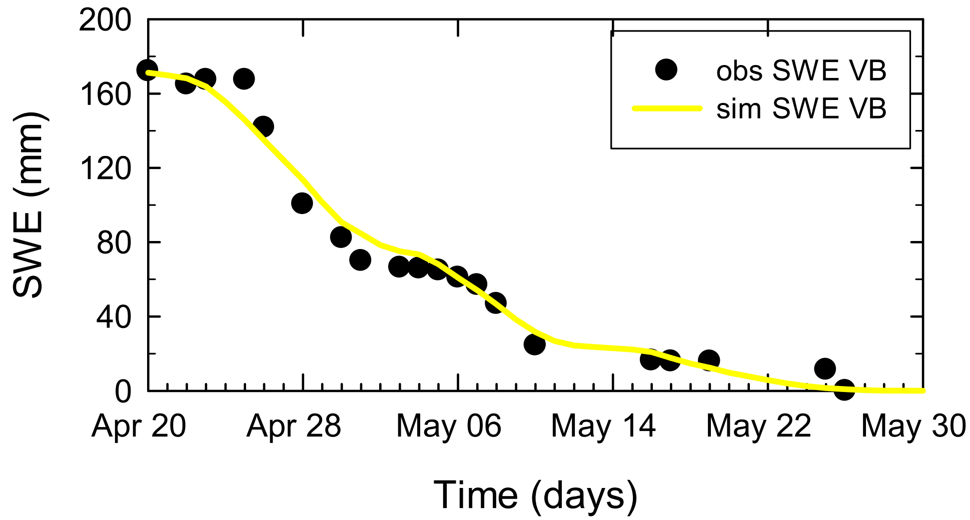
SWE - Calibration period - 2003



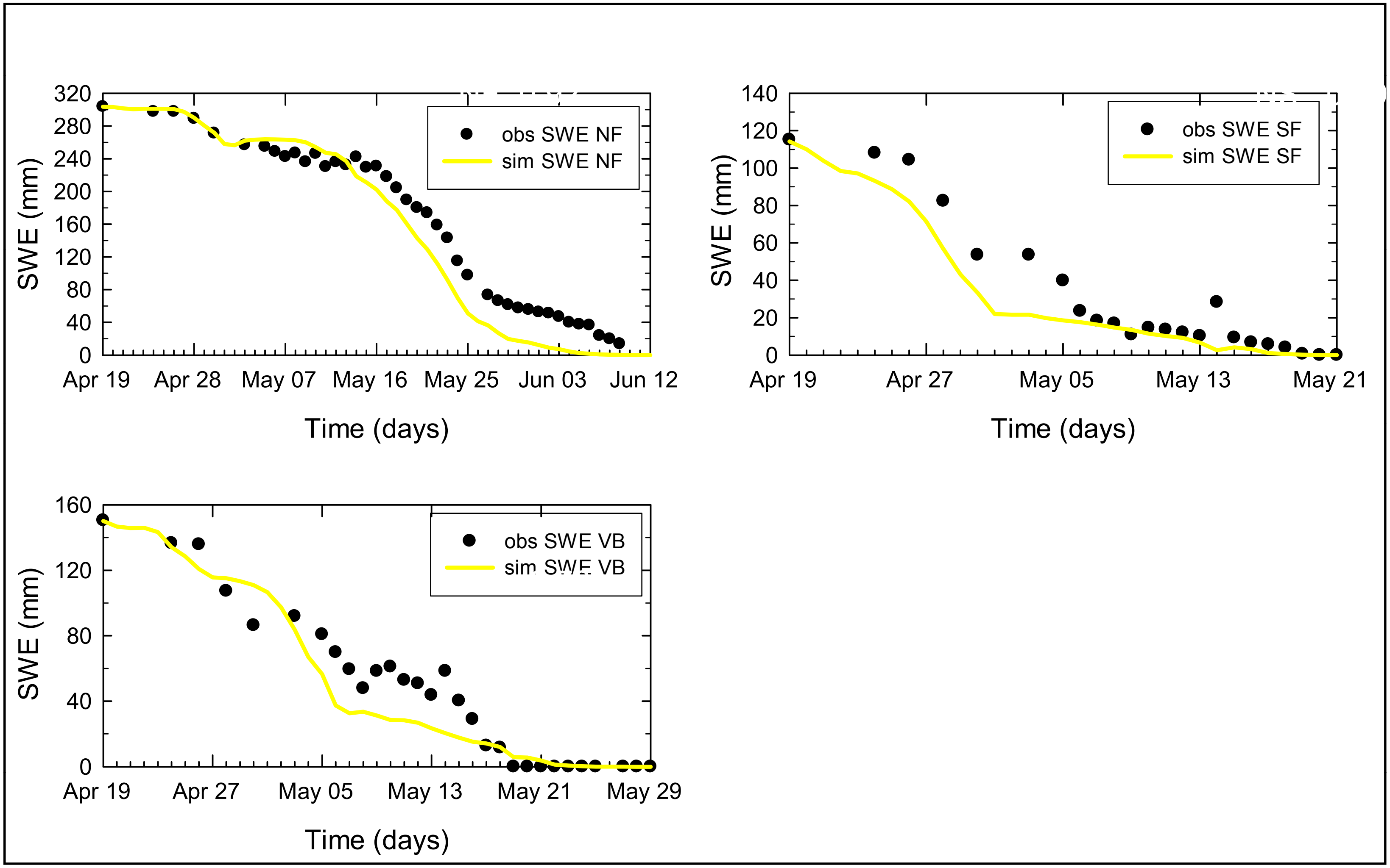


SWE - Calibration period - 2003

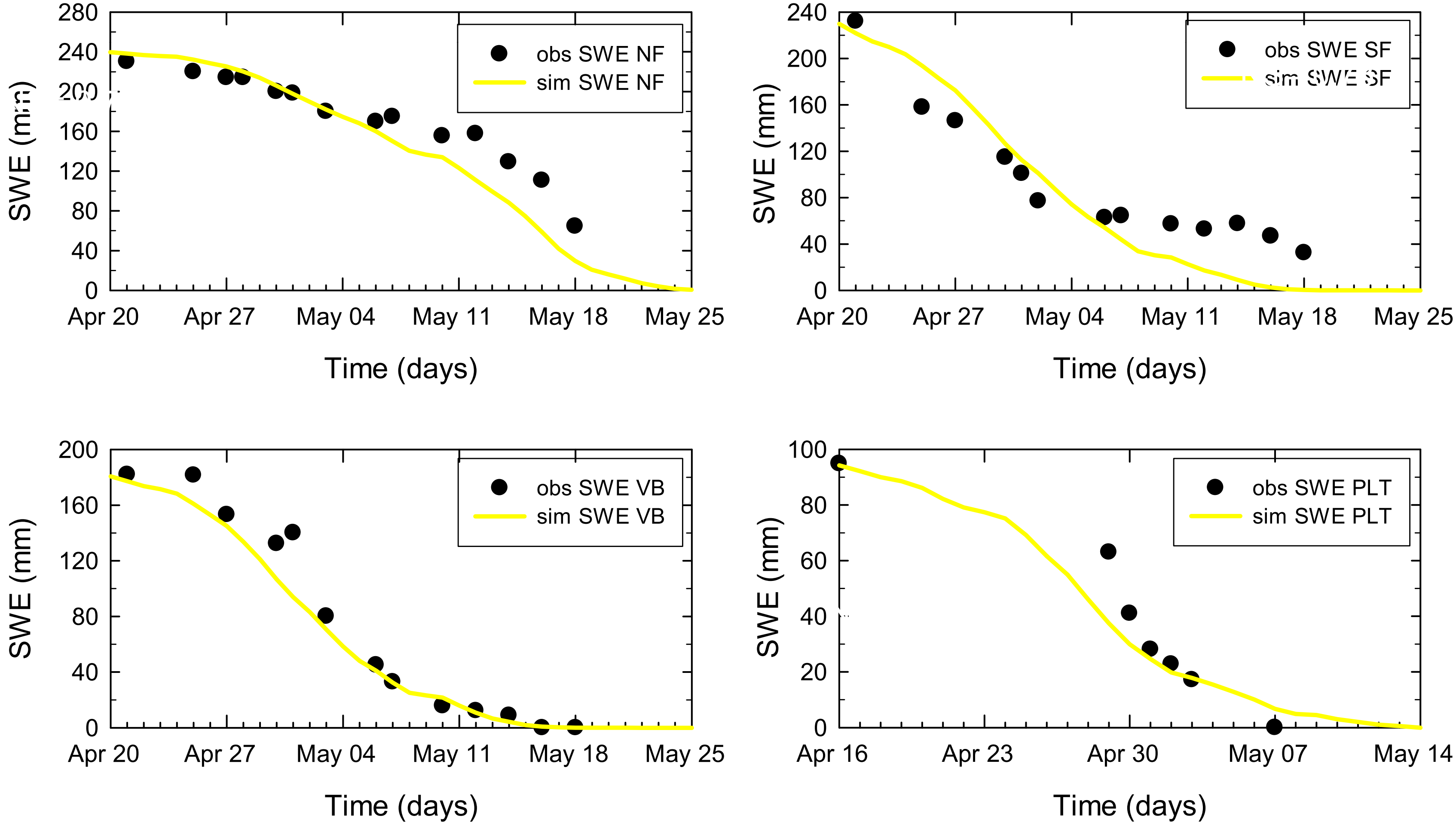




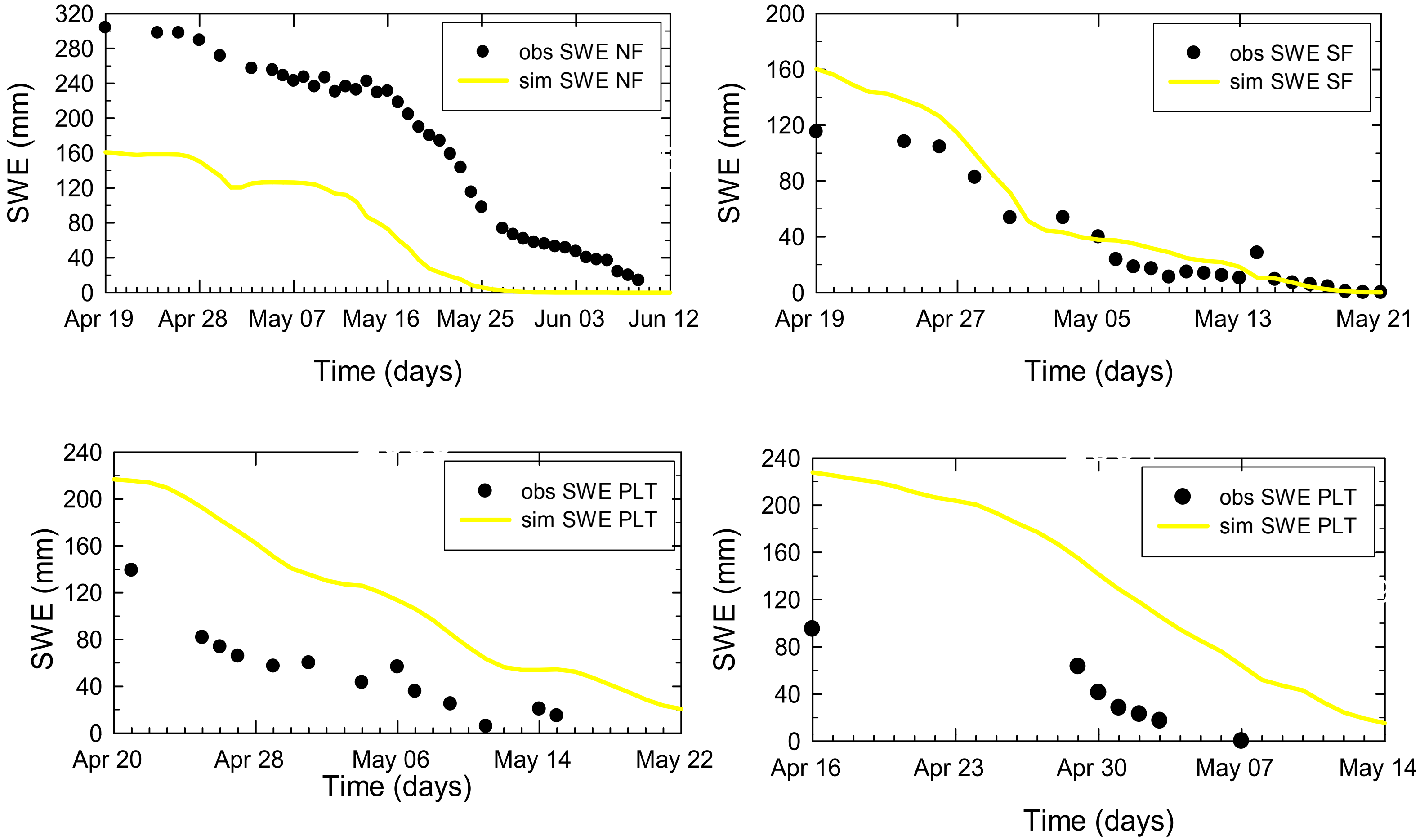
SWE - Validation period - 2002



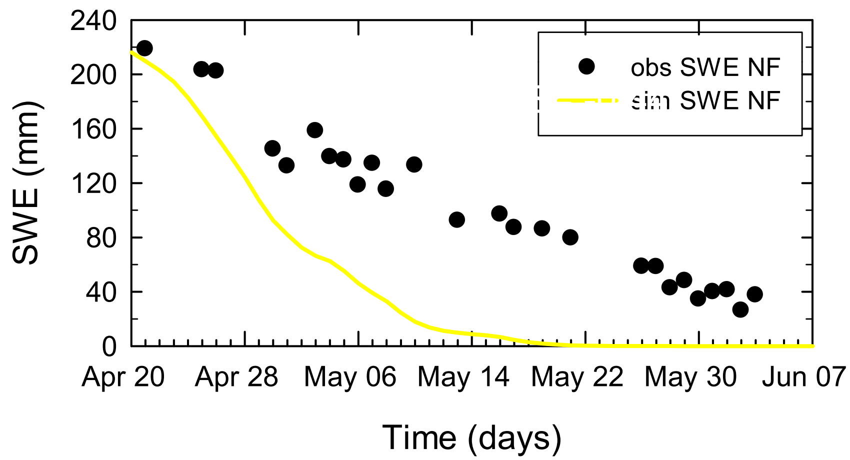
SWE - Validation period - 2004

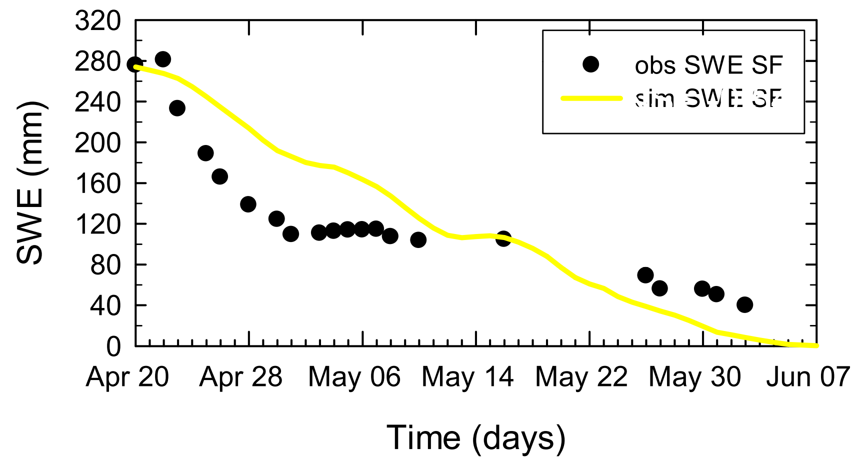


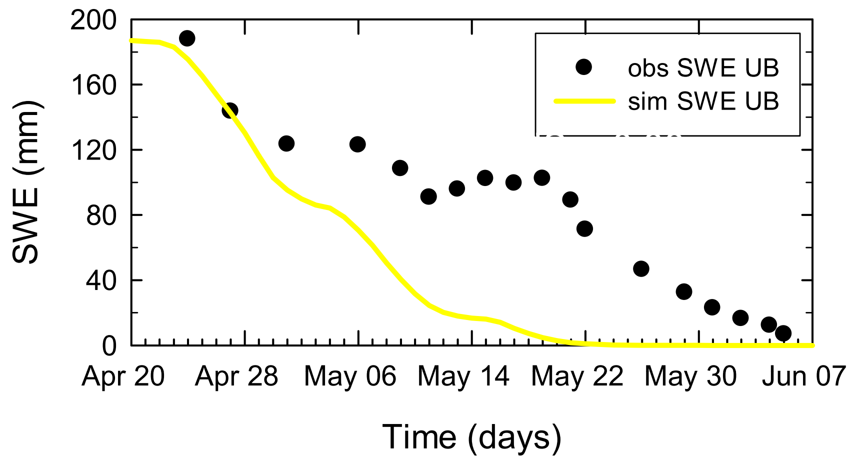
Avg. Initial Conditions



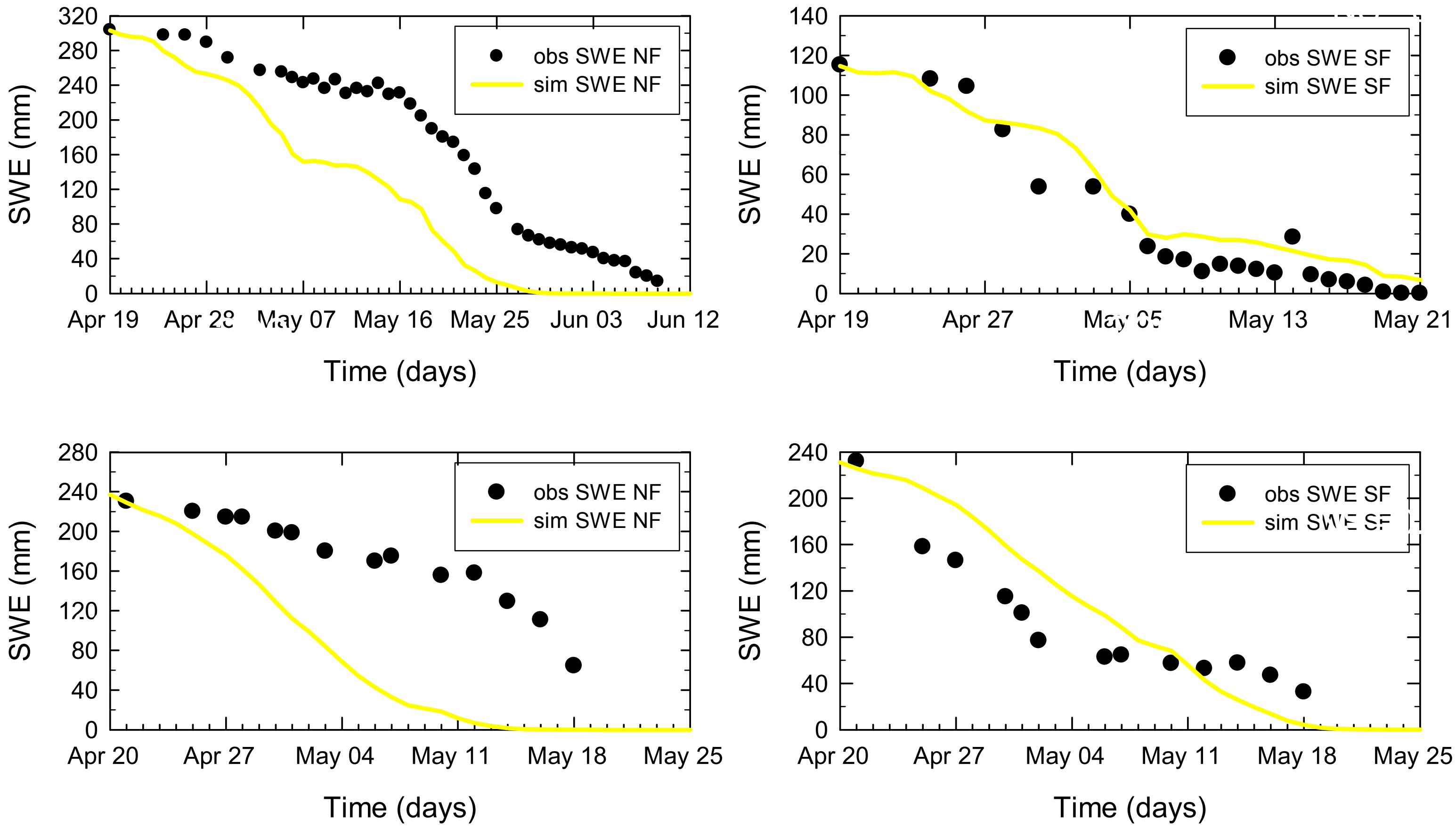
Aggregated Forcing data - 2003





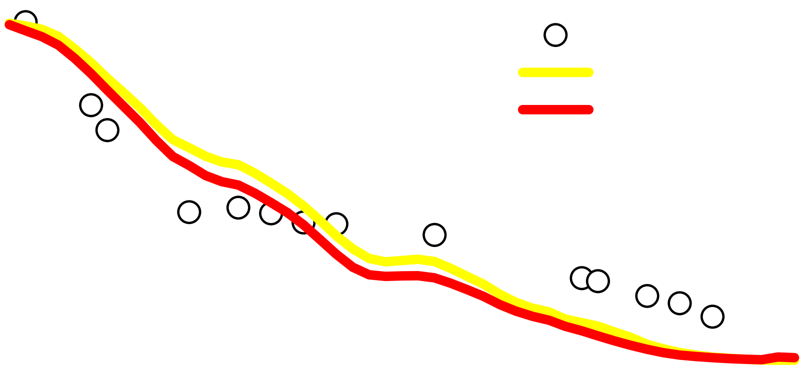


Aggregated Forcing data – 2002-2004

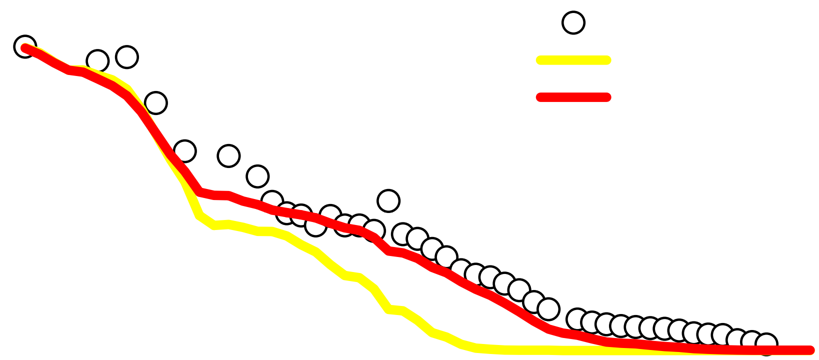


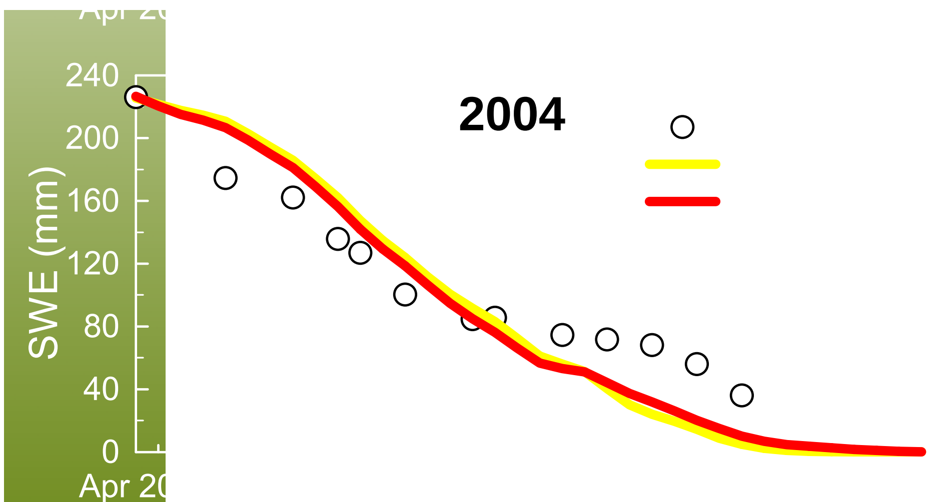
Aggregated vs Distributed

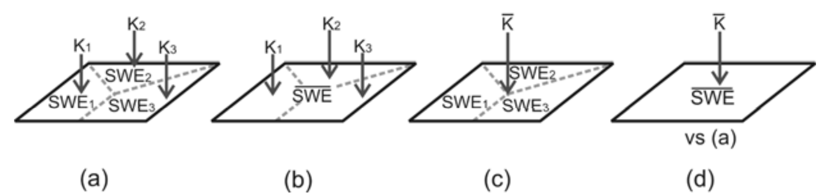
2003



2002

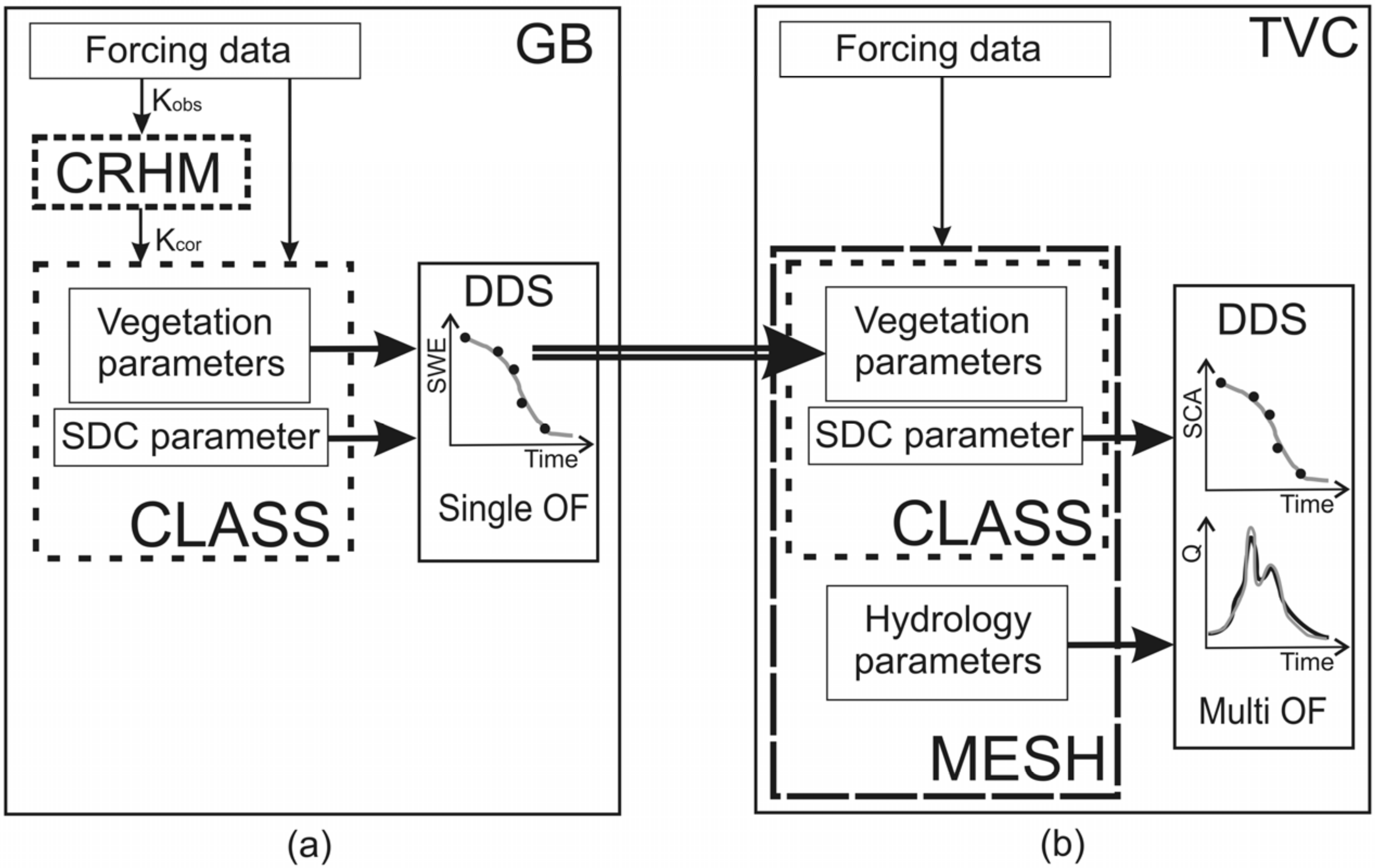






Modelling strategy

Transference of parameters



Modelling strategy

LS-Hydrological model

The MESH modelling system

Calibration 1996

Objective functions:

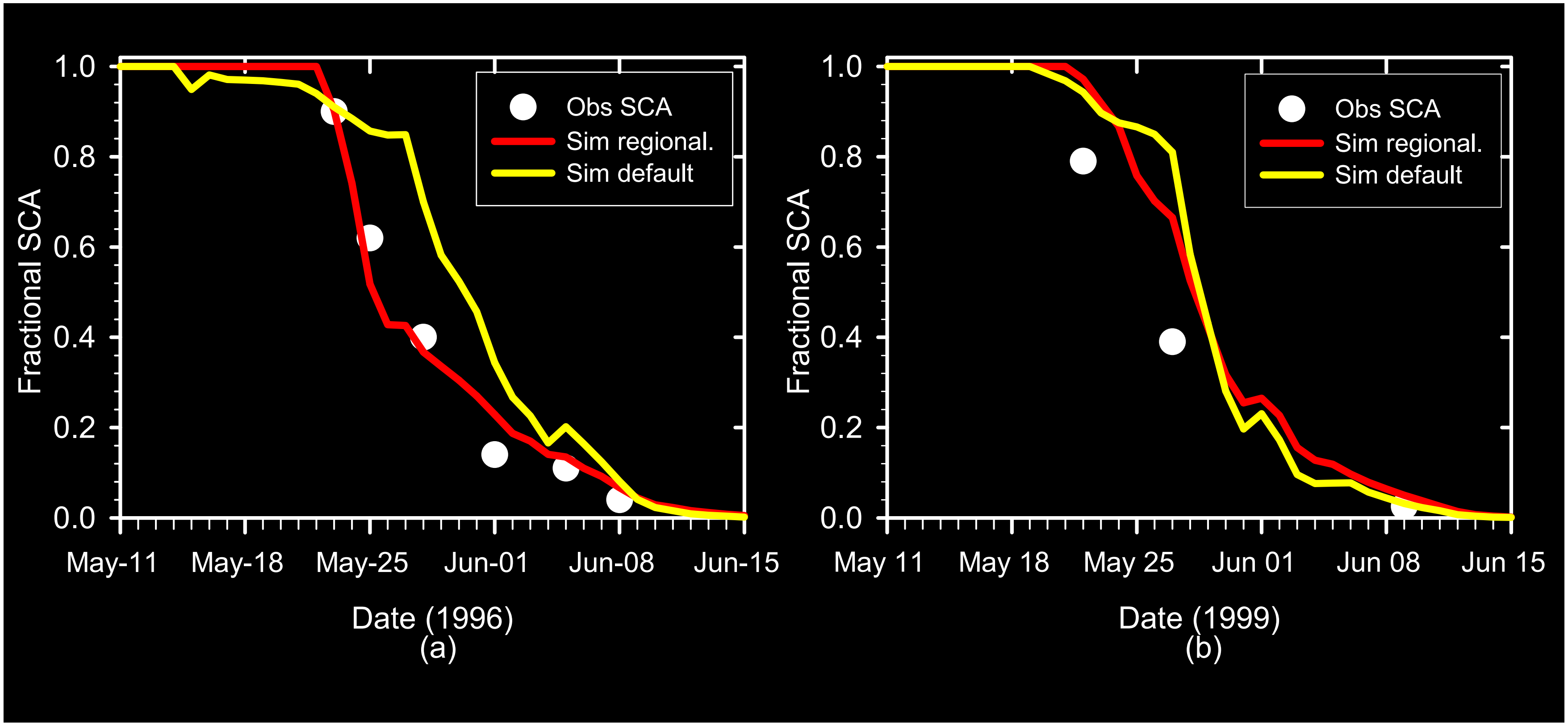
Streamflow and basin average Snow Cover Area (SCA)

Dynamically Dimensioned Search (DDS) global optimisation algorithm

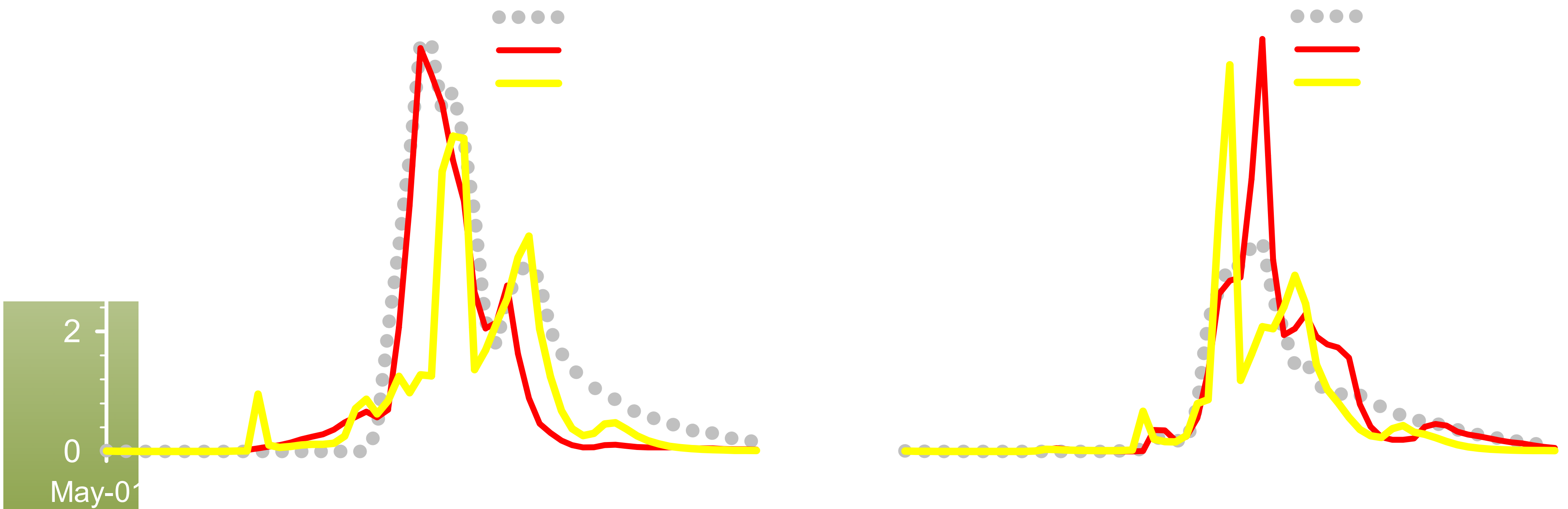
15 parameters (7 for shrubs, 7 for grass, and 1 for snow-cover depletion, SCD)

- Validation 1999

Trail Valley Creek - SCA



Trail Valley Creek - Streamflow



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Conclusions

- A regionalization approach for transferring parameters of a physically based LSH model in sub-arctic and arctic environments has been presented.
- This approach was based on a landscape similarity criterion and focused on two aspects.
  - First, model parameters are landcover-based rather than basin-based, and
  - second a step-wise calibration procedure was used to estimate the effective parameters.
- The landcover-based parameters offer an interesting alternative for PUB due to the difficulties in finding basin-based criteria for transferring parameters.
- Distributed and physically based models, landscape-based parameters appear to be a more feasible framework for transferring information between catchments than regionalisation schemes using regression methods based on basin characteristics.
- A special case however, was the inclusion of the SDC parameter in the calibration process at TVC. The main reasons were its poor physical basis and the resulting difficulty in deriving a landscape-base value from observations.

What Next

- Extend Wolf Creek analysis to entire basin
- Examine basin segmentation approaches and combinations of topographic and land-cover GRU’s.
- Look at continuous simulation to assess impacts on IC.
  - Tile connectors for redistribution of blowing snow
- Extend analysis to other basins
- Pay attention to IP-1 and IP-2 findings