Land-Surface-Hydrological Models for Environmental Prediction

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IP3
Improved Processes & Parameterisation for Prediction in Cold Regions

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  - Diana Verseghy and Paul Bartlet for advice on CLASS
  - Bryan Tolson for assistance with DDS
  - Nick Kouwen for WATFLOOD help
  - many other ……

Challenges of Hydrologic Predictions

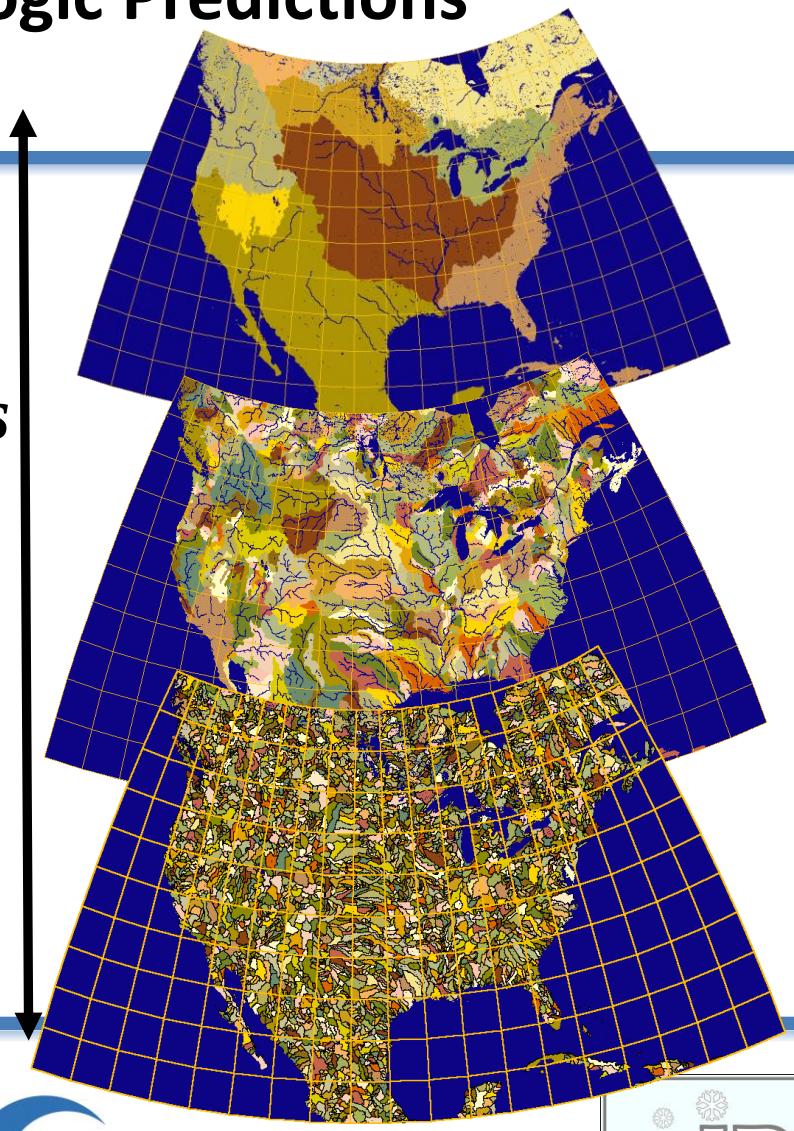
Continental Scale:

Focus of Hydro-Climate modelers

Watershed Scale:

(Where hydrology happens)

Focus of Hydro-Met. Modelers



Courtesy of : Dr. Soroosh Sorooshian,
University of California Irvine

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Required Hydrologic Predictions

Short Range – · – · – · – · – · – · – · – Long Range

hours --------> **days** --------> **weeks** --------> **months** ------> **year**

Flash Flood Warning

Flash Flood Guidance

Headwater Guidance

Flood Forecast Guidance

Reservoir Inflow Forecasts

Spring Snow Melt Forecasts

Water Supply Volume

Hindcast and Now cast – Planning and design

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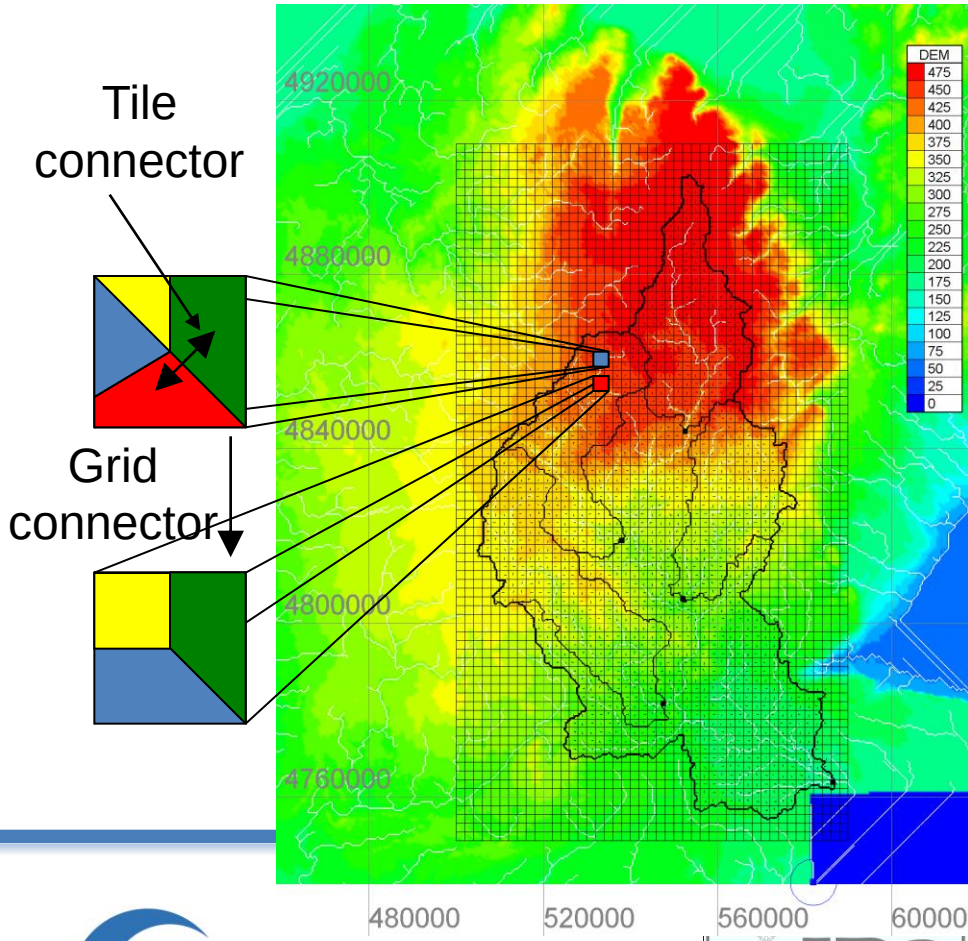
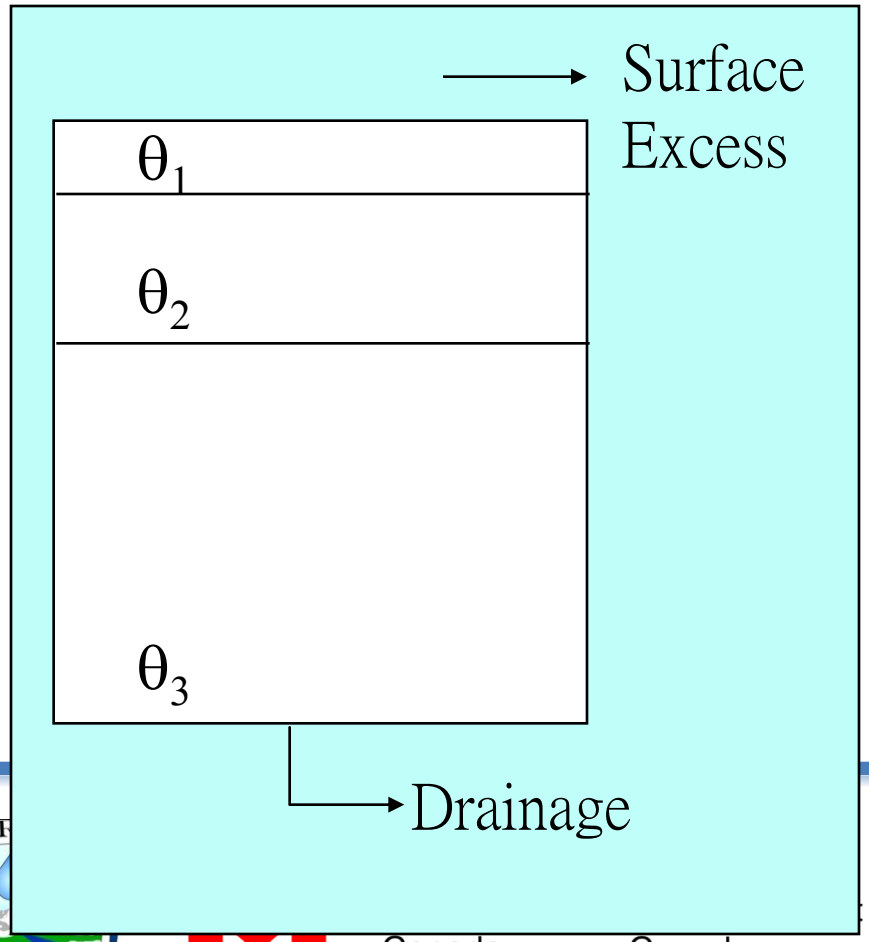
MESH: A MEC surface/hydrology configuration designed for regional hydrological modeling

- 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

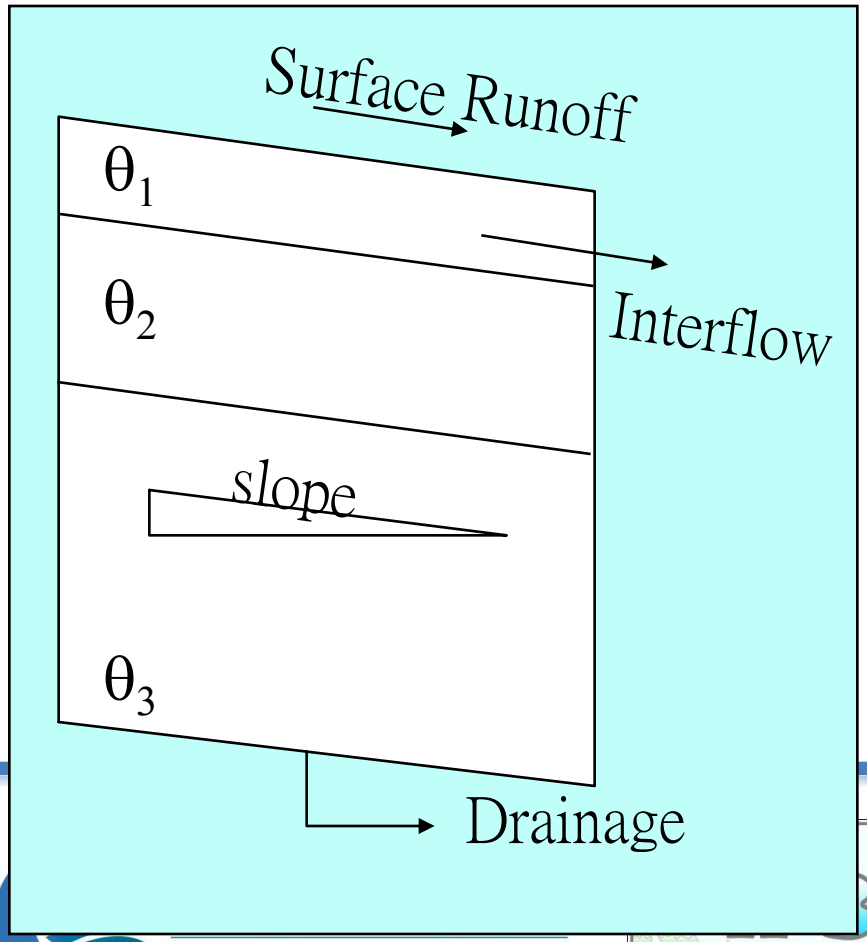


Improved Soil Water Balance

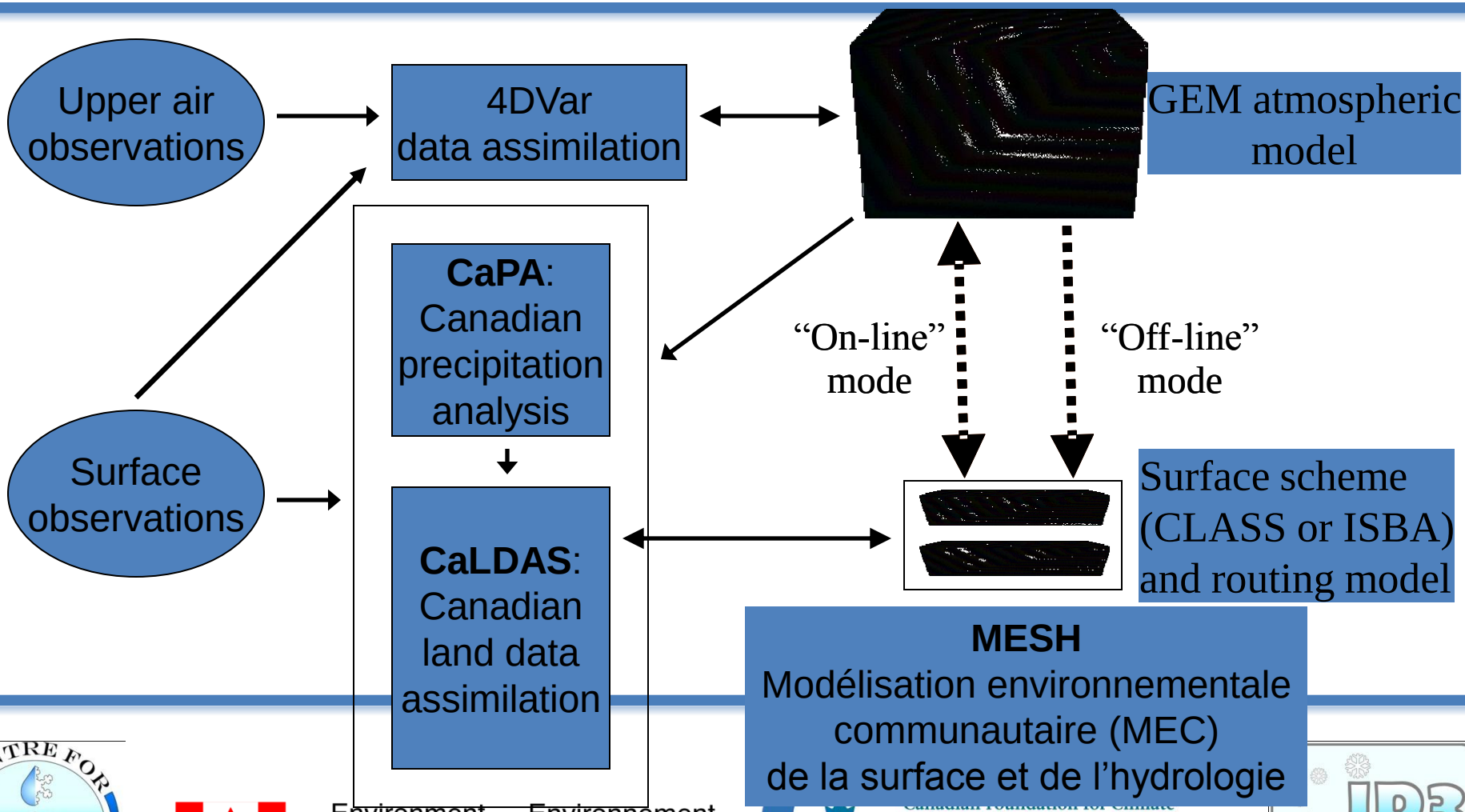
CLASS 2.7 Model



MESH (CLASS 3.5)



Environmental Prediction Framework



HOW TO COMBINE INDUCTIVE AND DEDUCTIVE APPROACHES TO PREDICTION IN UNGAUGED BASINS

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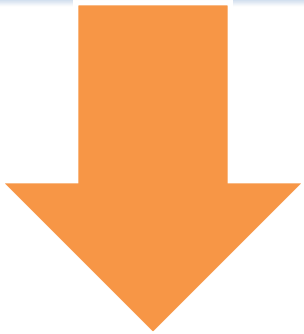
PHILOSOPHIES OF MODELLING



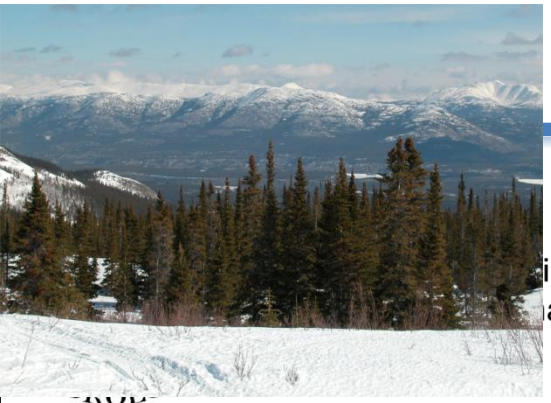
Inductive Approach – Top Down

• Analyses processes based on data (e.g. dominant responses) at larger scales (e.g. basin) and then, if needed, make inferences about processes at smaller scales.

Deductive Approach – Bottom-Up

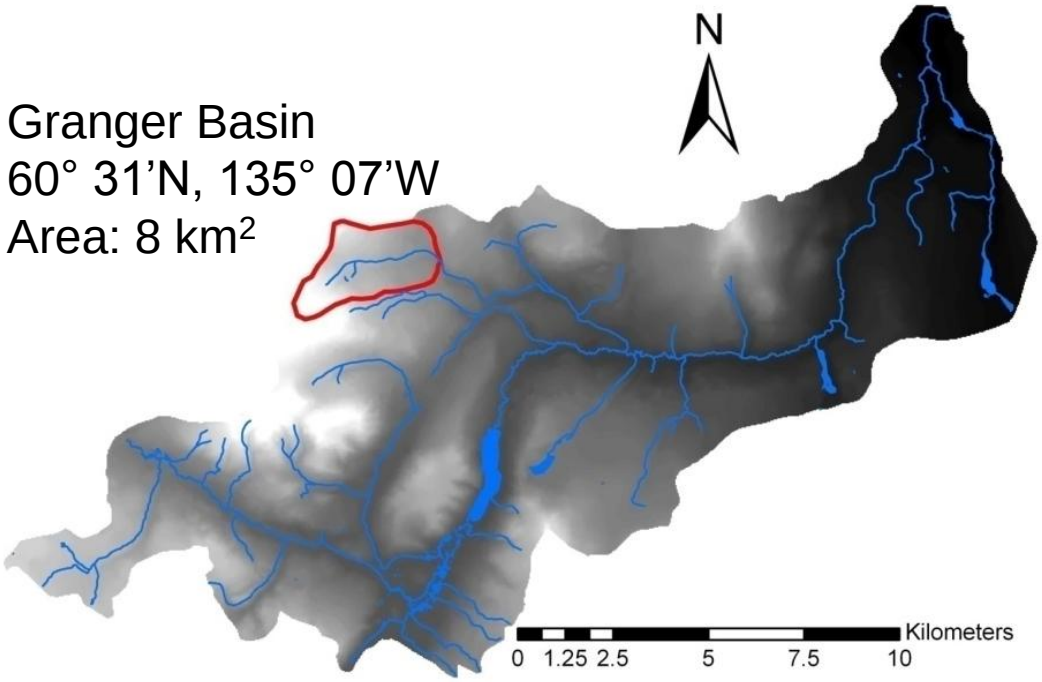
• Analyses processes at smaller scales using physical laws, and then extrapolates the process at larger scales using aggregation techniques.

Study Area



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

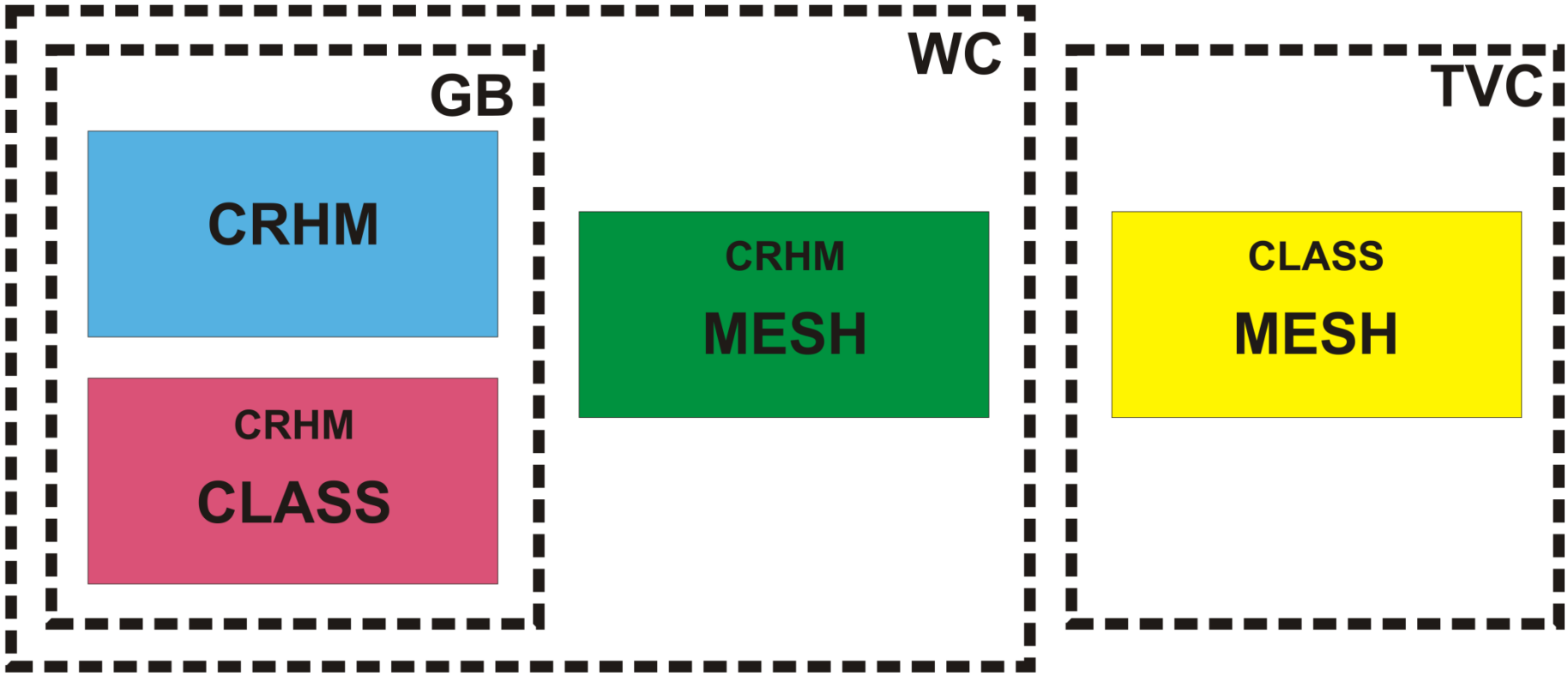
Granger Basin
60° 31'N, 135° 07'W
Area: 8 km^2



Modelling Methodology

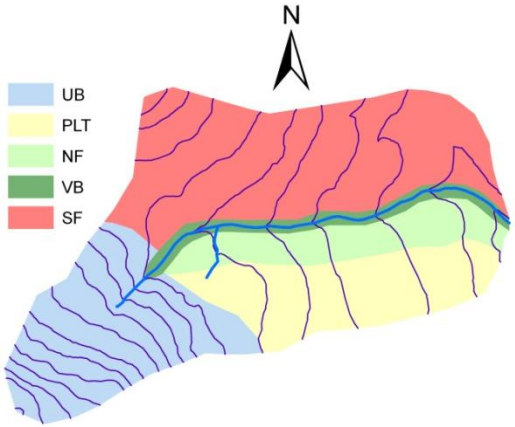
Three models:

- Small-scale physically based Hydrological Model (CRHM)
- Land Surface Scheme (CLASS)
- Land Surface Hydrological Model (MESH)



LANDSCAPE HETEROGENETY

Granger Basin



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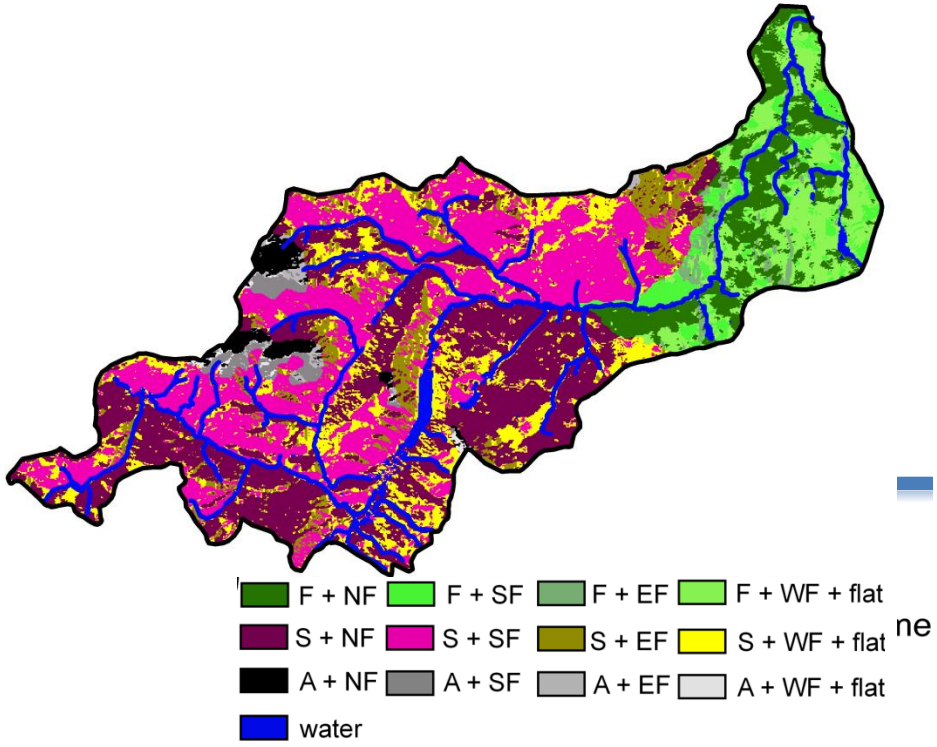
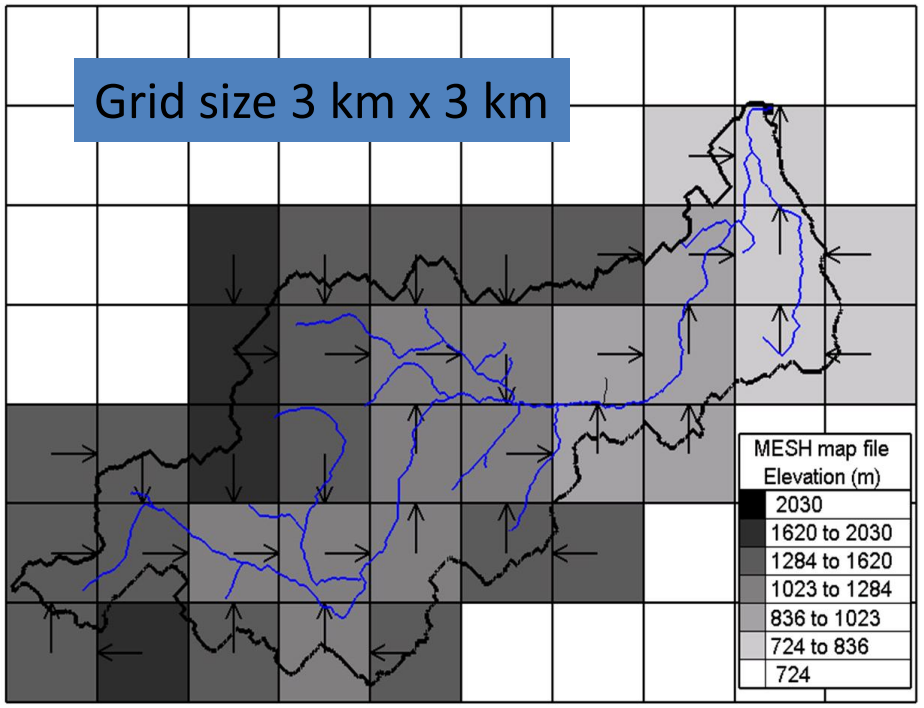
HYDROLOGICAL LAND SURFACE SIMULATIONS

Snowcover ablation and Snowmelt runoff using MESH

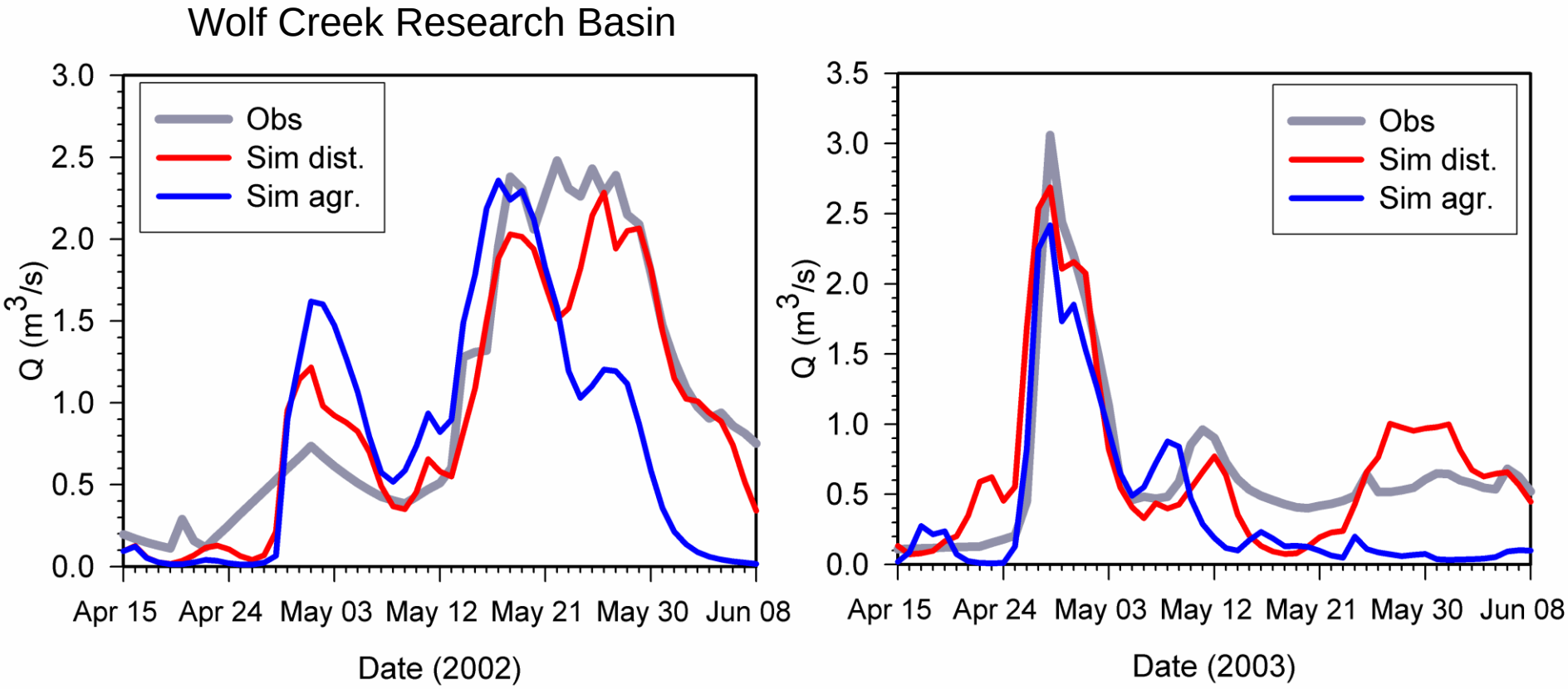
Spatial representation based on the GRU approach

- Definition of GRU based on:
  - Topography and vegetation cover

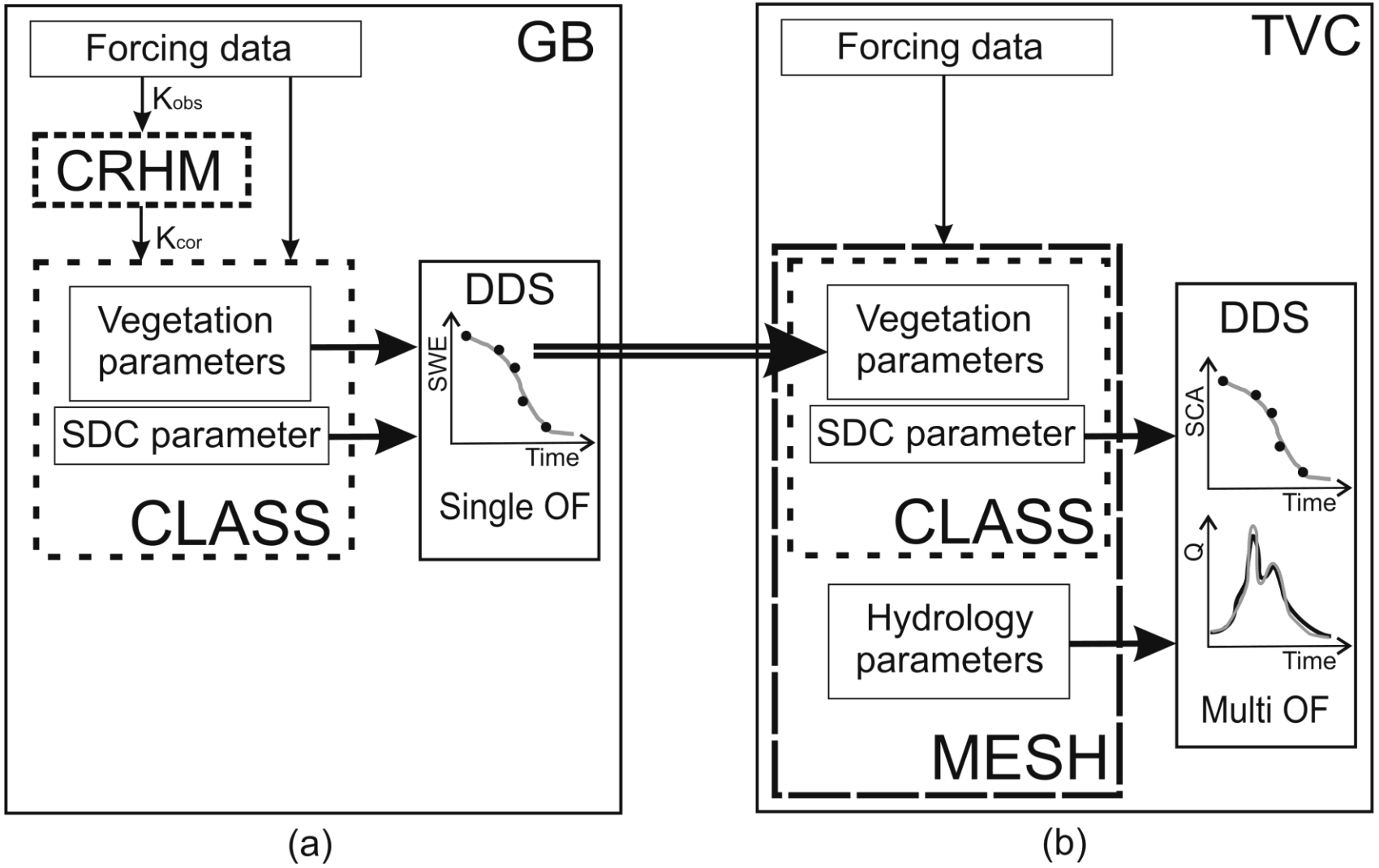




BASIN STREAMFLOW SIMULATIONS



LANDSCAPE BASED APPROACH TO REGIONALISATION



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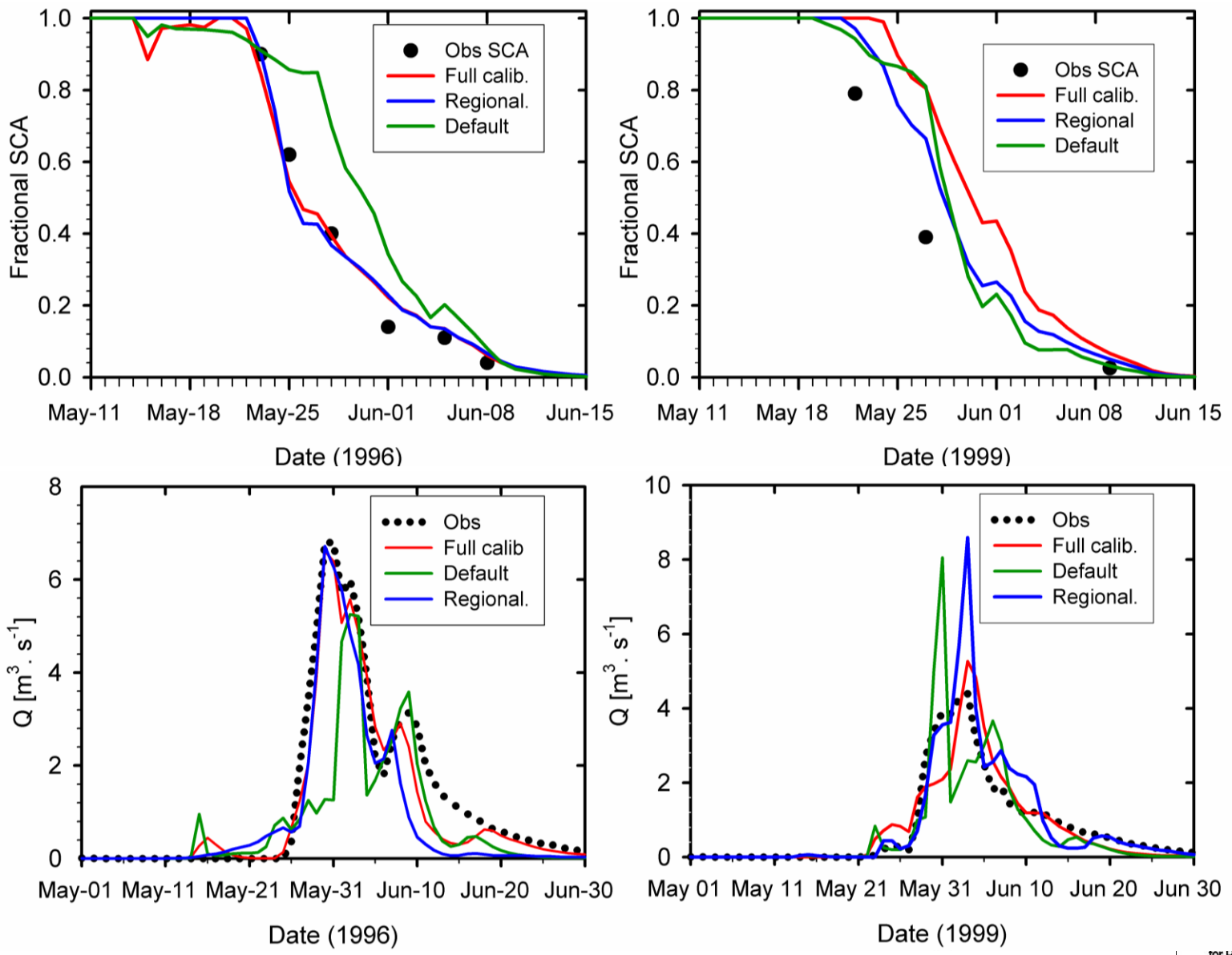


IP3'S MODELING APPROACH

CONTENTS

- Top-down & bottom-up modeling approach
- Scale-free parameter regionalization
- Case studies
  - The South Saskatchewan River Basin (SSRB) and
  - The Upper Assiniboine River Basin
- Results

TOP-DOWN & BOTTOM-UP MODELING APPROACH

- Use literature based parameter values for the LSS model
- Step by step include lateral flow processes and calibrate parameters only related to the lateral flow processes

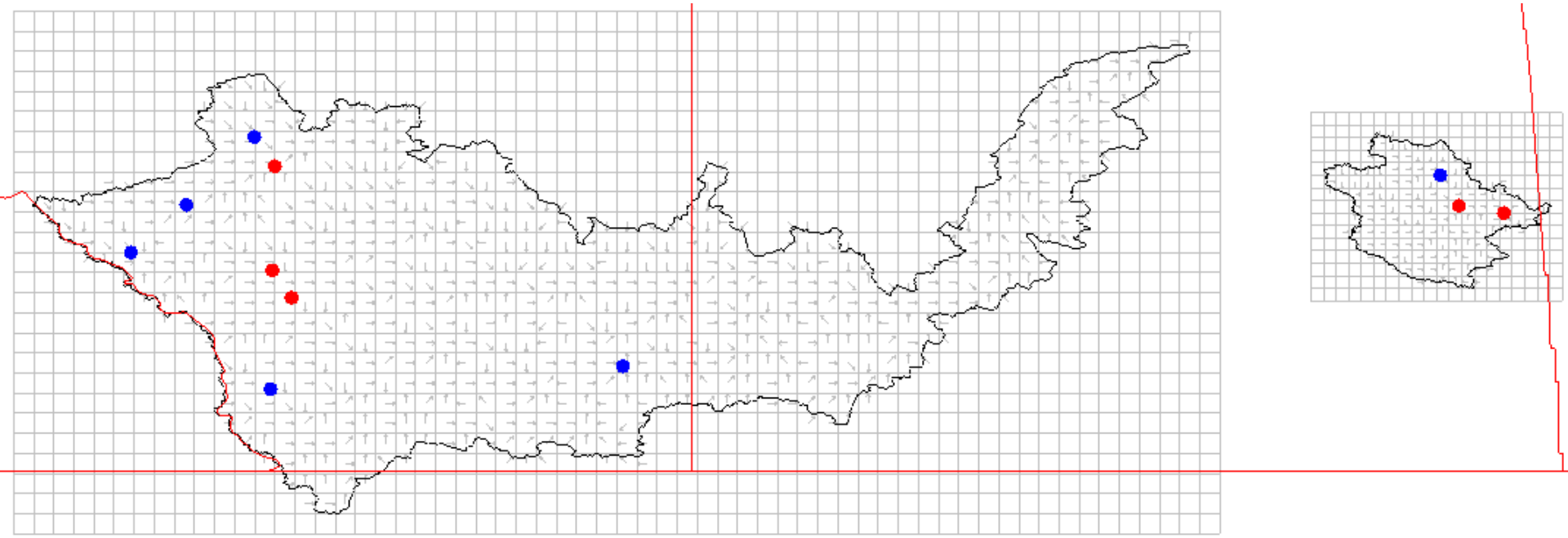
SCALE-FREE PARAMETER REGIONALIZATION

- Combining the GRU approach with sub-basin based parameter calibration
- Validate consistency of parameter values in both time-space dimensions
- Hence parameter values are transferrable within the basin (without bringing in scaling issues)!

CASE STUDIES – SSRB and ASSINIBOINE

	SSRB	ASSINIBOINE
Grid size (degrees)	0.2 X 0.2	0.125 X 0.125

Stations in blue – Calibration and validation (time dimension)
Stations in red – Validation in space dimension



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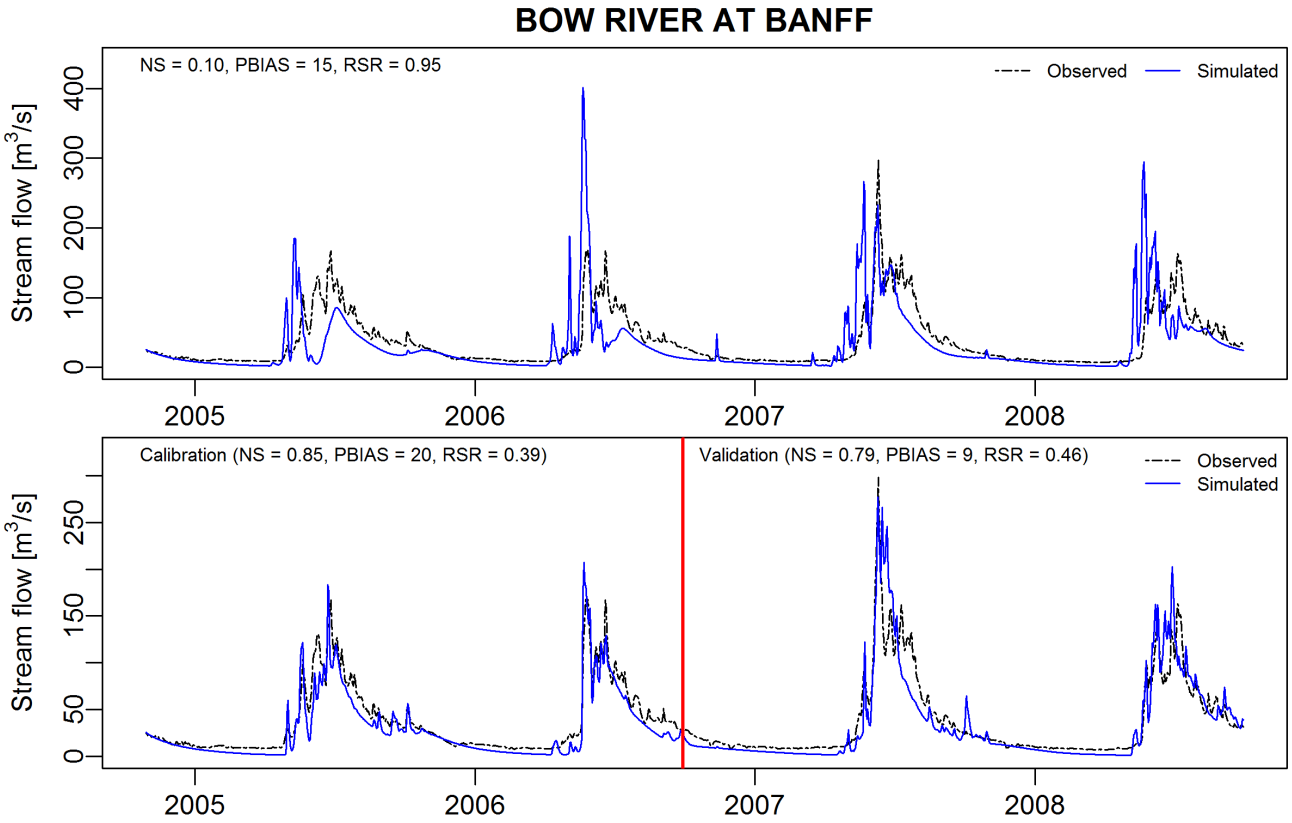
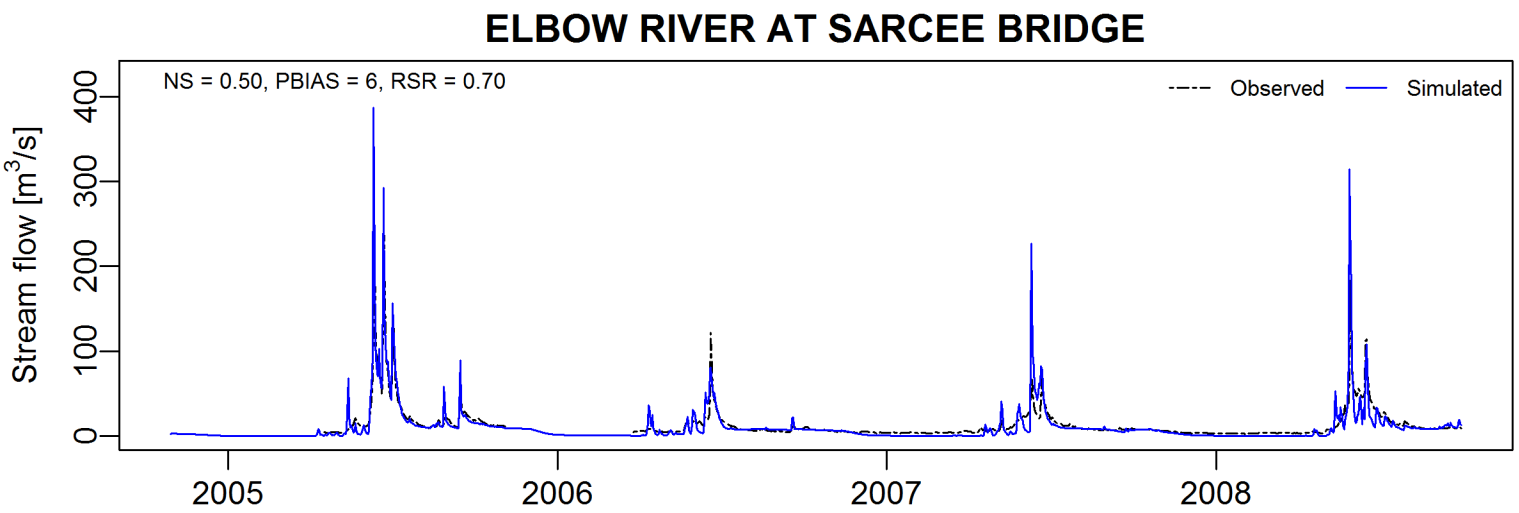
RESULTS – SSRB – COARSER GRID

- More improvements by including lateral flow process
  - Model grid size - 0.2 degrees by 0.2 degrees
  - 6 land classes
  - 5 sub-basins to calibrate and validate (time dimension) model parameters
  - 3 independent sub-basins to spatially validate calibrated parameter values

OUT-OF-THE-BOX VERSUS LATERAL FLOW PROCESSES INCLUDED



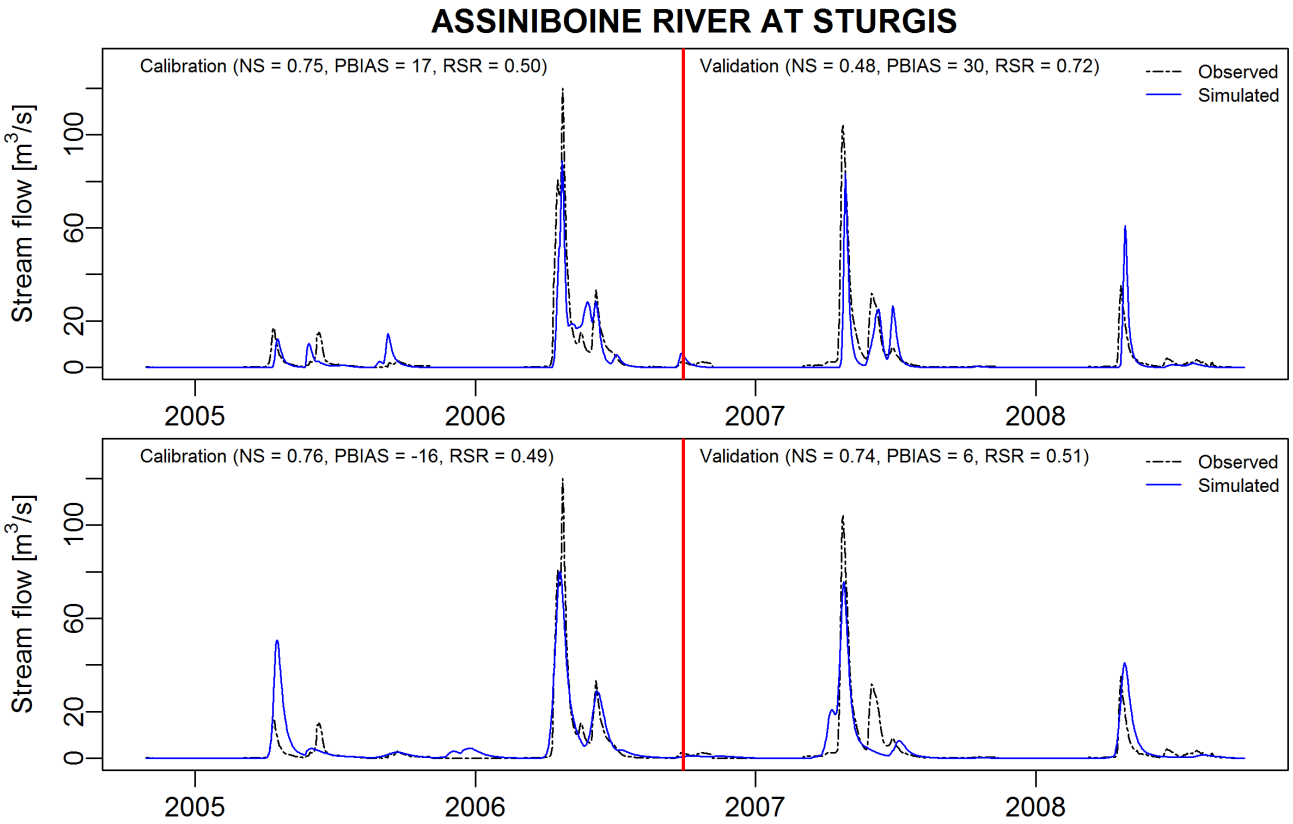
SPATIAL VALIDATION USING INDEPENDENT SUB-BASINS



RESULTS – ASSINIBOINE – FINER GRID

- Further improvements by including the frozen soil infiltration algorithm
  - Model grid size - 0.125 degrees by 0.125 degrees
  - 4 land classes
  - 1 sub-basin to calibrate and validate (time dimension) model parameters
  - 2 independent sub-basins to spatially validate calibrated parameter values

WITH AND WITHOUT THE FROZEN MODULE – CALIBRATION AND VALIDATION



WITHOUT FROZEN MODULE

WITH FROZEN MODULE

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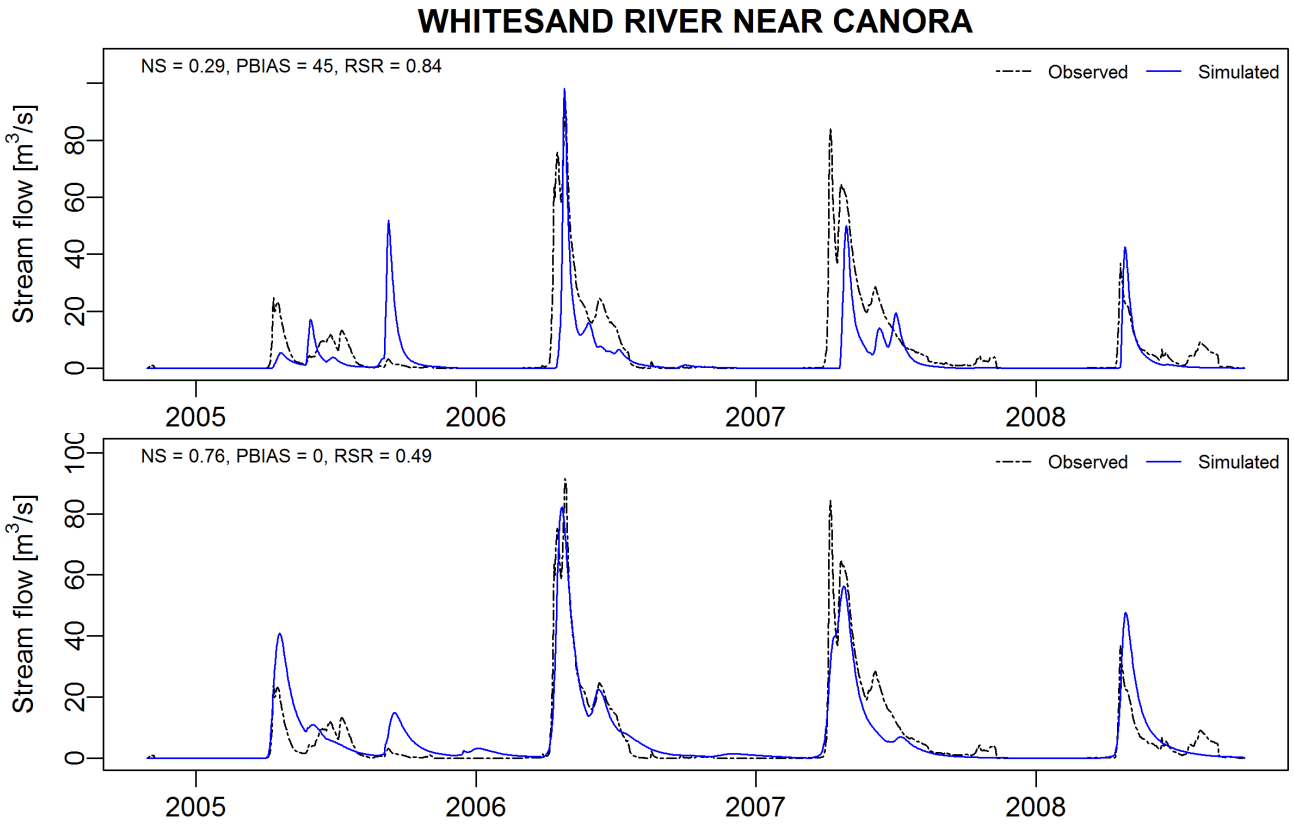
WITH AND WITHOUT THE FROZEN MODULE – SPATIAL VALIDATION



WITHOUT FROZEN MODULE

WITH FROZEN MODULE

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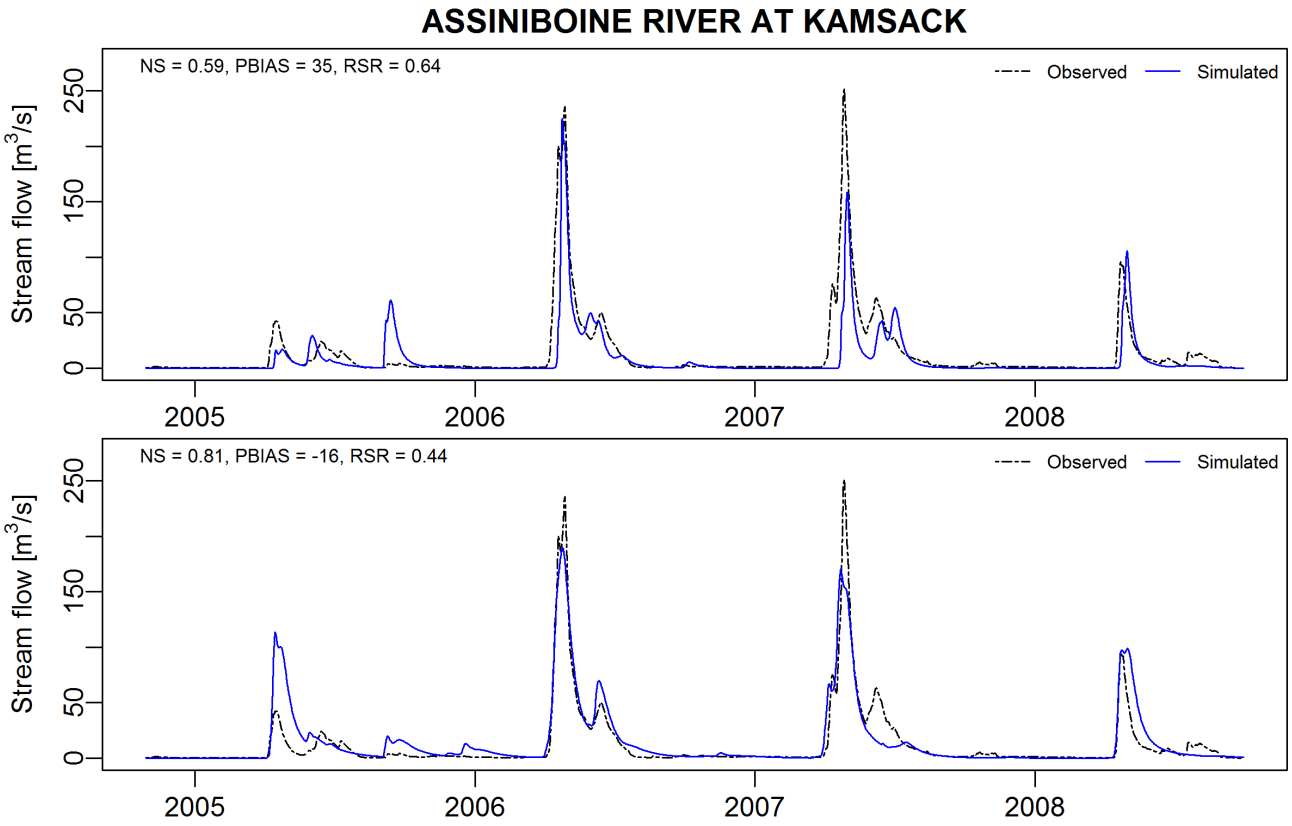
WITH AND WITHOUT THE FROZEN MODULE – SPATIAL VALIDATION



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Conclusions

- Small scale process studies were successfully used in a bottom-up approach to assist in calibrating and segmenting the basin in a large-scale “top-down” type of modeling system.
- Landscape-based parameters used in vertical water budget estimates that were calibrated in one basin have some validity when used in other basins. At the large-scale, the GRU approach allows for consistent landscapes parameterization provided we have sufficient information for validation in space and time.
- Large Scale modeling of the Saskatchewan and Assiniboine River systems were successful using a landscape based approach with MESH.
- Further refinements to the model (parameterization and some aspect of physics) particularly dealing with basin segmentation and grid size still needs to be considered.
- MESH and CHRM form a complimentary modeling platform that allow for rigorous testing from the bottom-up and the top down. With the Sask River basin and the upper Assiniboine testing completed, we are in the enviable position of looking at scale effects on hydrological modeling while quantifying to some degree the importance or need for calibration and important scale dependencies for physical processes and parameterizations.
- Because we are running coupled system with the atmosphere, the sensitivity and importance of parameterization for closing water budget (comparing to hydrographs) should impact in a positive way our ability to predict short-term weather and also improve our ability to engage in improved regional climate modeling.