Hydrogeologic controls on low flow dynamics

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Projekt low-Flow, financed through the BAFU

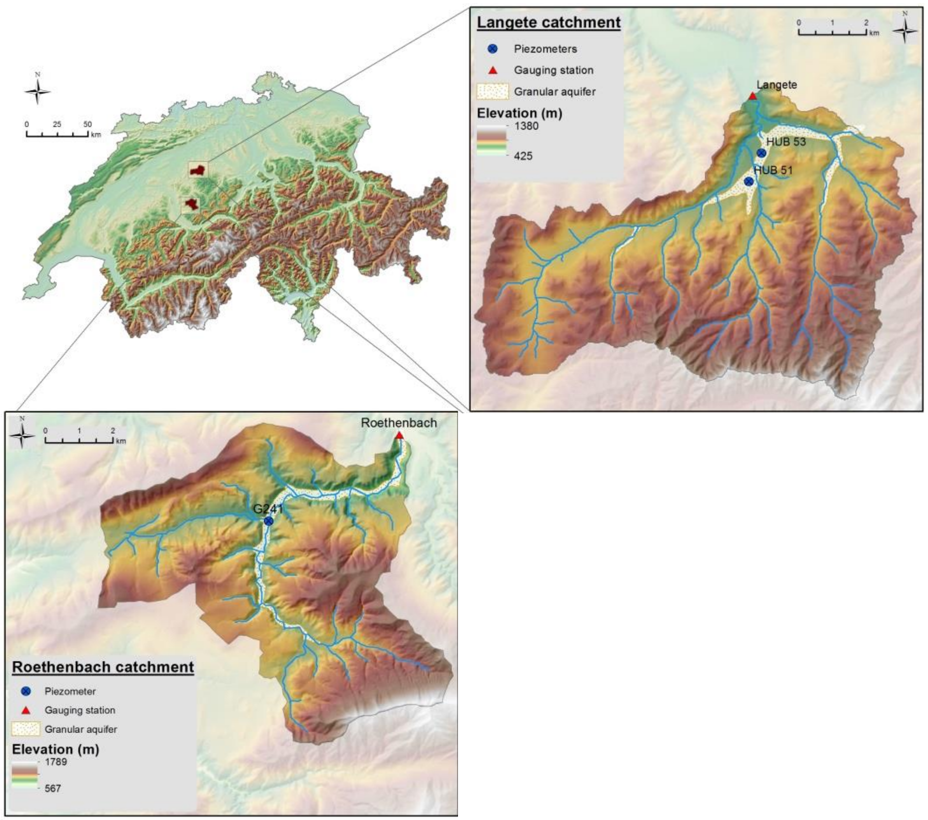
Introduction

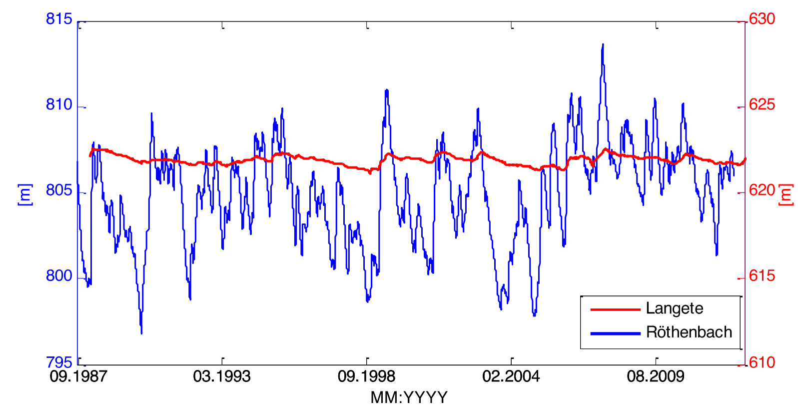
Context: Climate change can increase occurence of water shortage

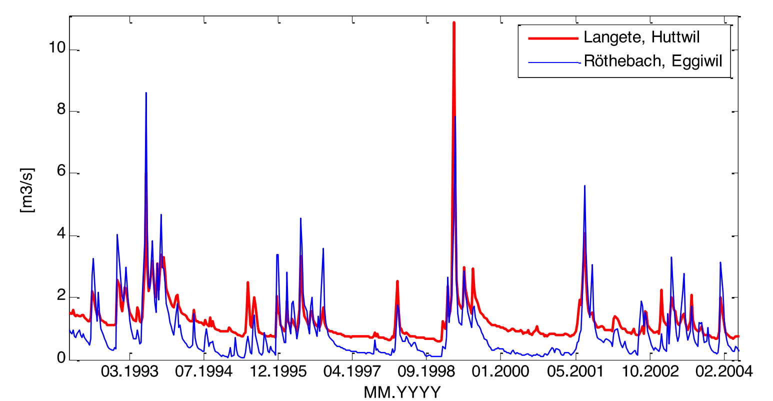
Challenges:

- Process understanding is limited
- Current tools are inadequat

Introduction



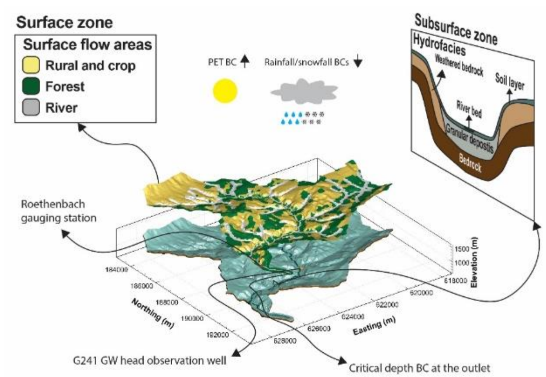




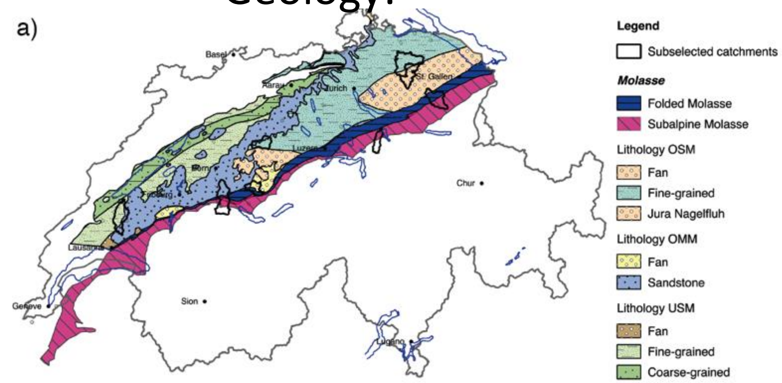
Methodology

- Process understanding:

Physically based models

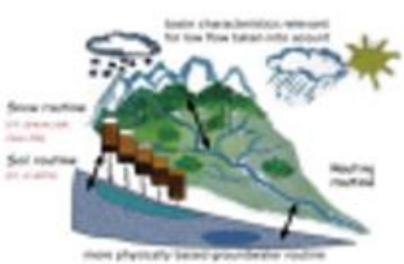


Geology:

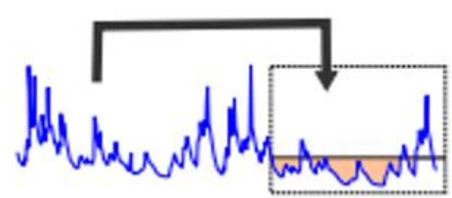


- Improvement of current tools

HBV models



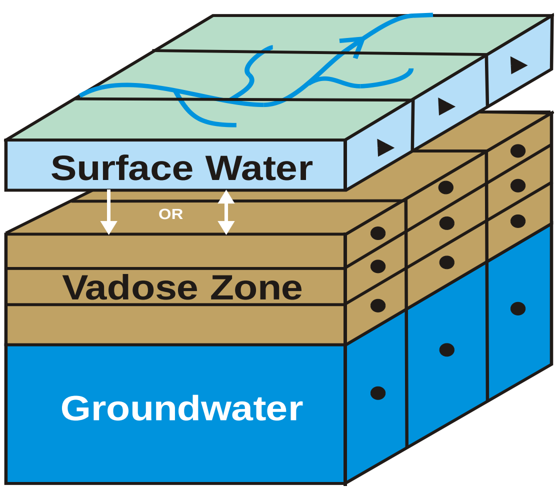
Hydrograph analysis



Simulation approches:

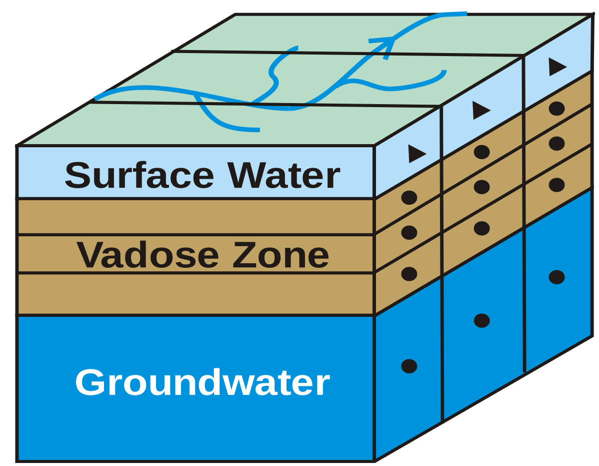
- Reservoir-type (e.g. HBV)
- Independent (decoupled) simulation of surface and groundwater
- Coupled surface-subsurface simulations

Linked Solution:



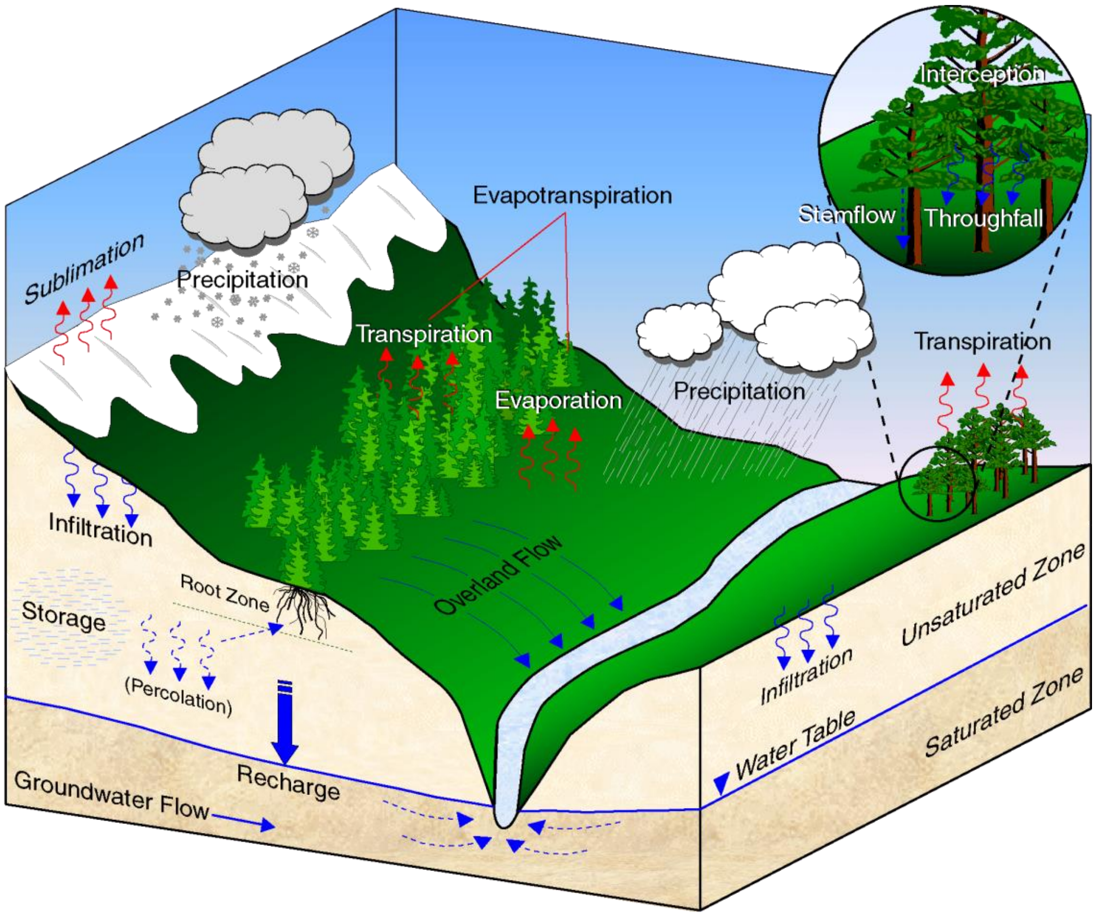
- Non-iterative
- Iterative
- Coupling head or flux

Fully Coupled Solution:



R. Therrien

HydroGeoSphere:



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Global Objective

- Simulate the complete hydrologic cycle

Integrated models

- Attempt to account for all interactions between surface and subsurface flow regimes
- Simultaneously solve surface and subsurface flow & transport equations

Approach: physical properties control on catchment low-flow dynamics

- Synthetic HGS models: identification of physical properties controlling catchment dynamics under dry conditions

- Detailed HGS models: higher scale validation with two existing catchments

PhD-project Claire Carlier

HGS synthetic models: set up

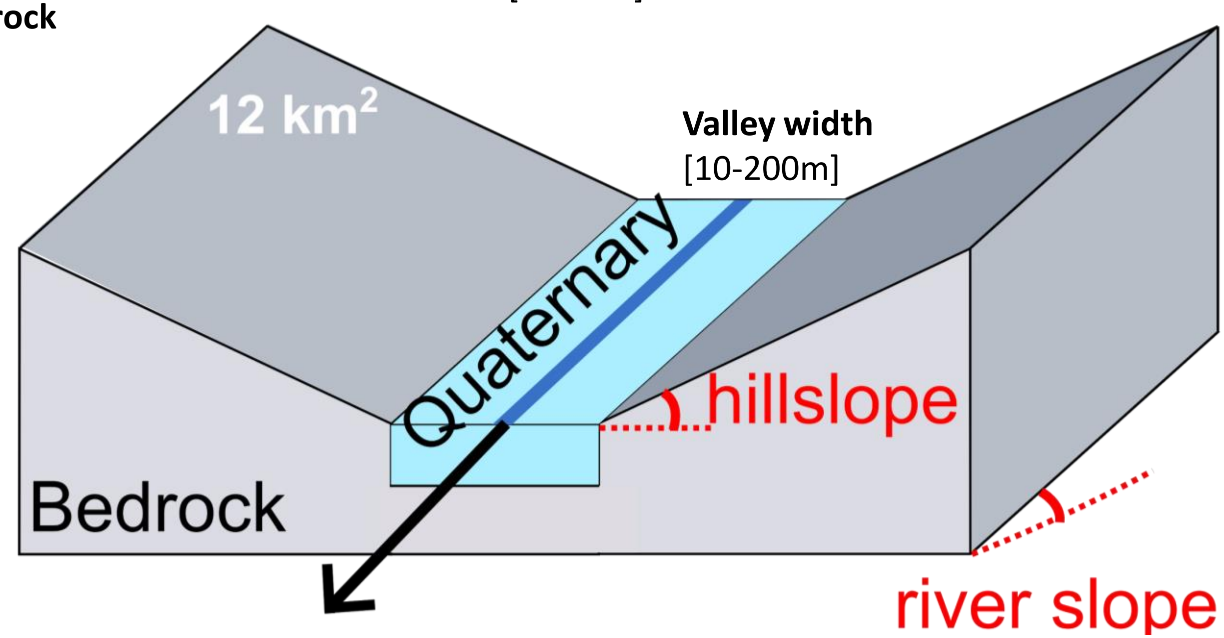
K quaternary valley
[10^{-7} - 10^{-2} m/s]
Porosity quat.
[0. 1-0.4]

K bedrock
[10^{-7} - 10^{-4} m/s]
Porosity bedrock
[0.001-0.2]

Hillslope
[5-50%]

Valley width
[10-200m]

Basin/river slope
[0.5-15%]



Additional variations:

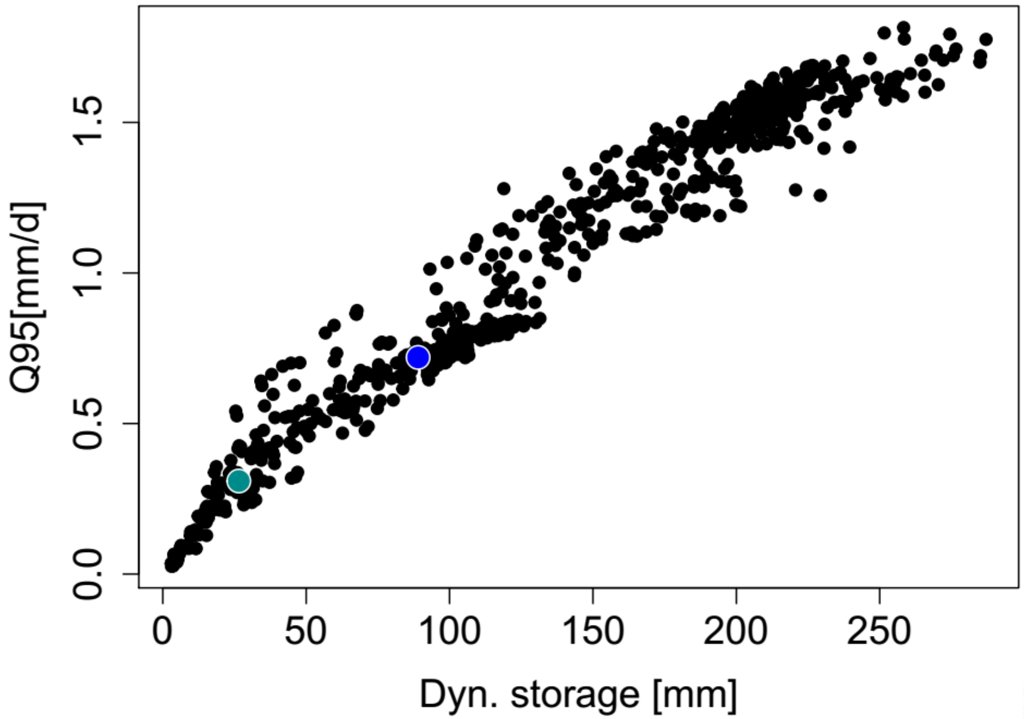
Size: 9-27 km^2

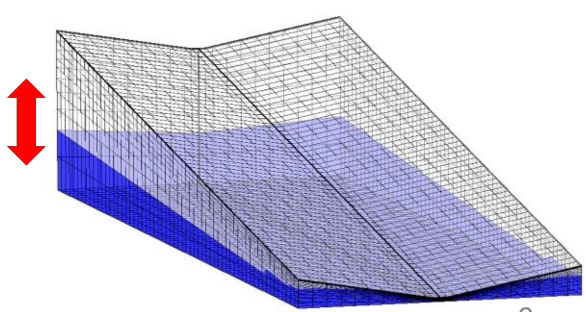
Aspect ratio

Precipitation

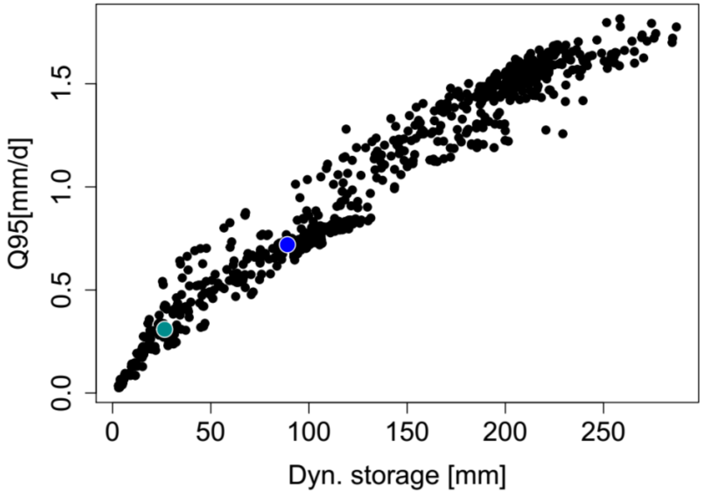
$$Q_{catch.} = Q_{riv.} + Q_{GW}$$

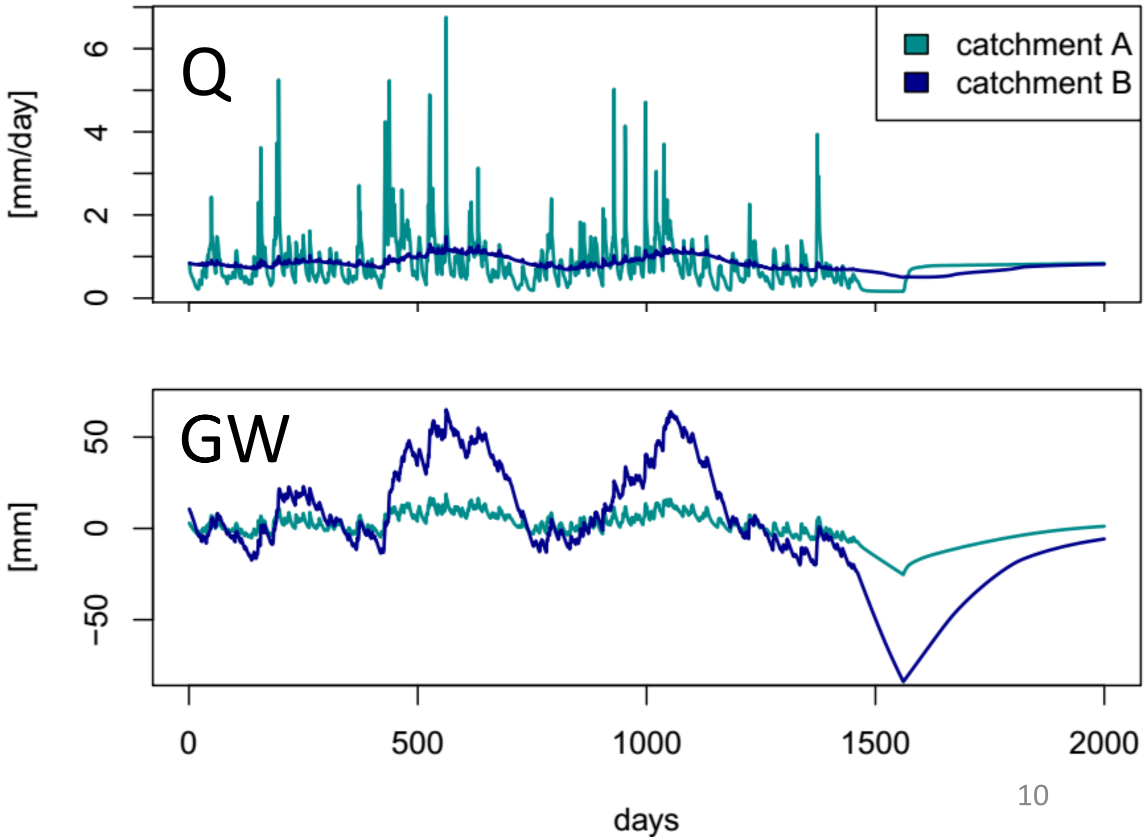
Synthetic HGS models: GW versus low-flows dynamics



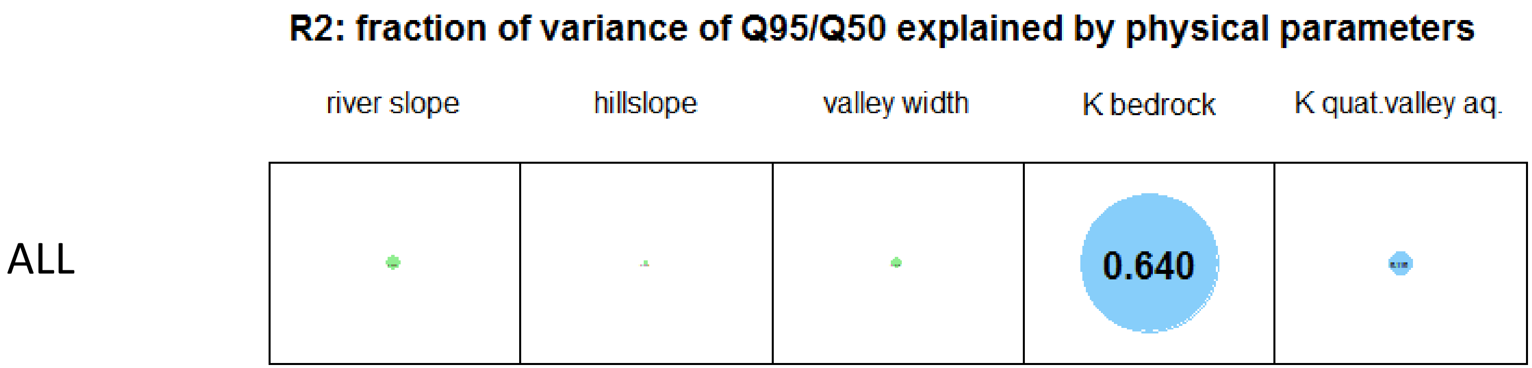


Synthetic HGS models: GW versus low-flows dynamics



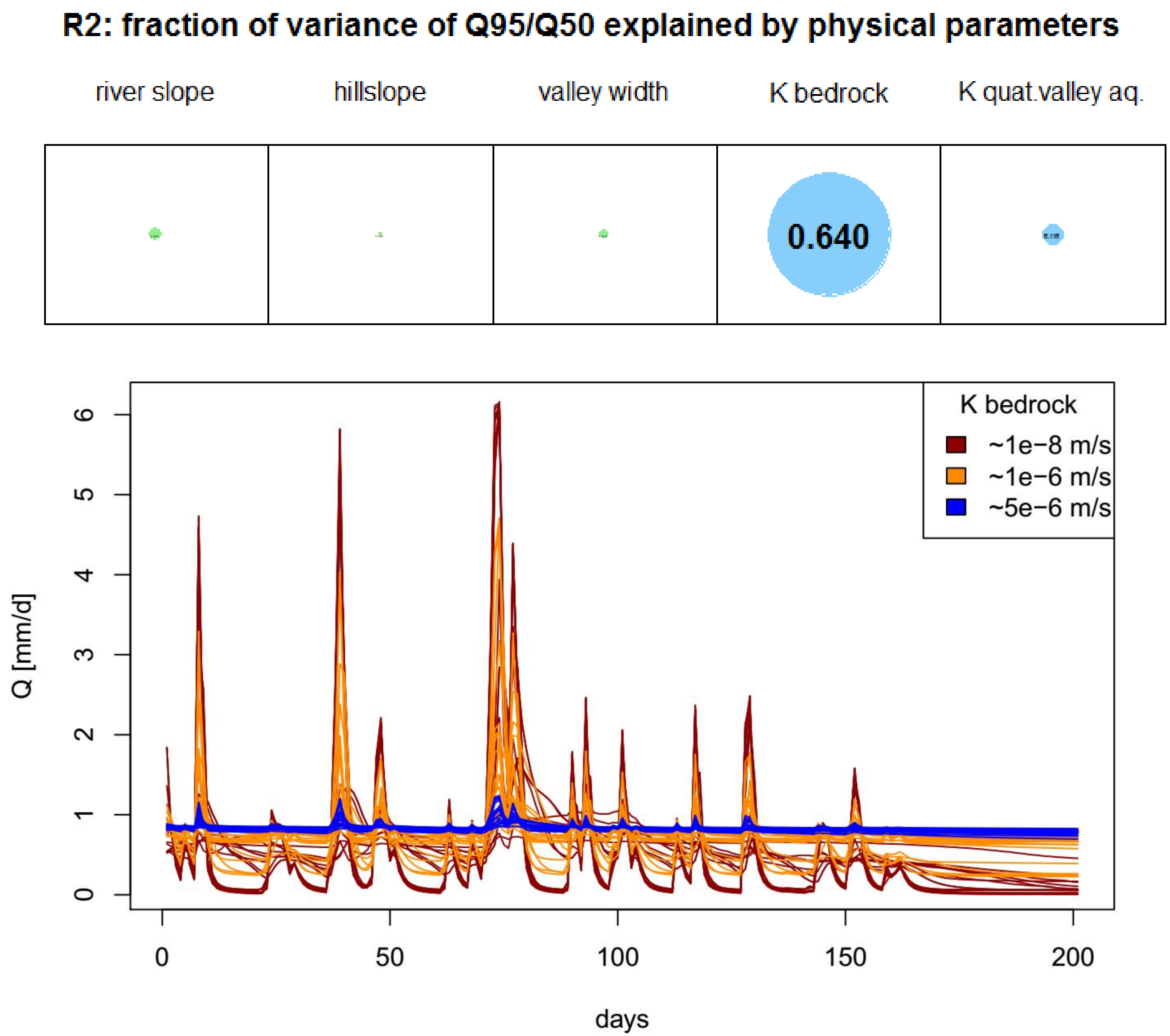


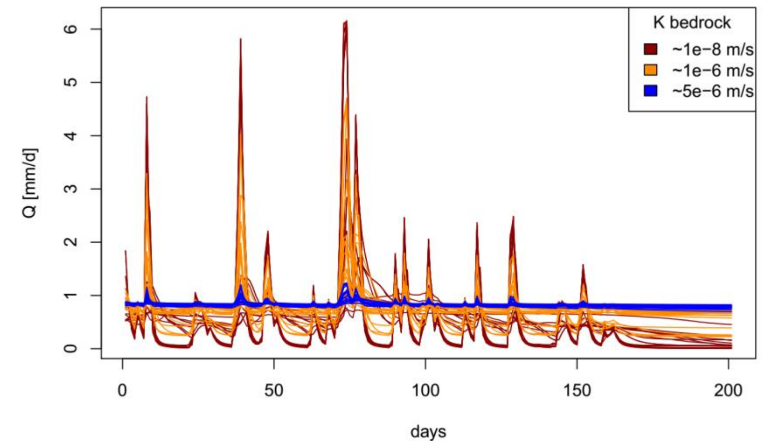
Synthetic HGS models: controlling properties



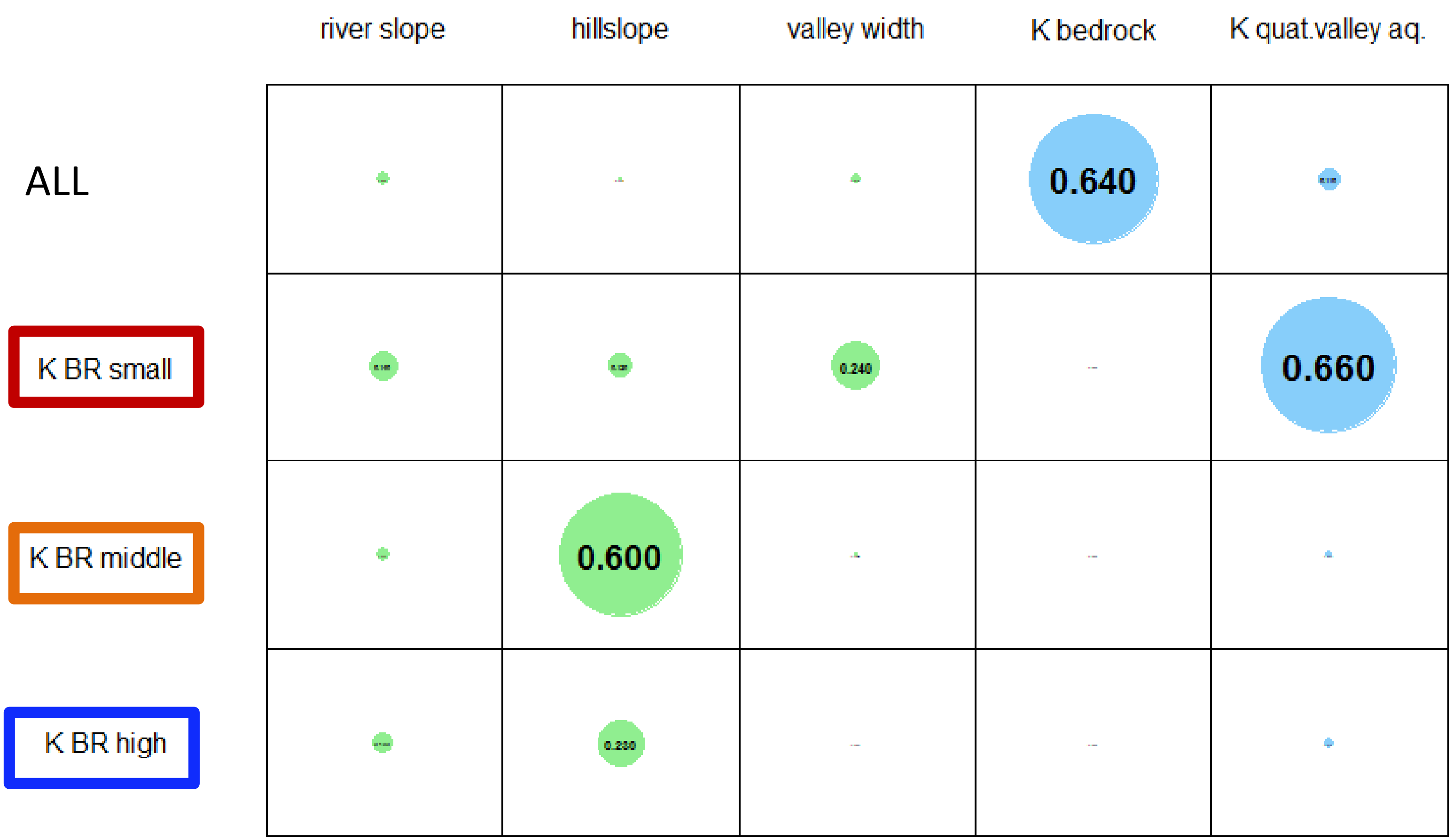
Synthetic HGS models: controlling properties

ALL

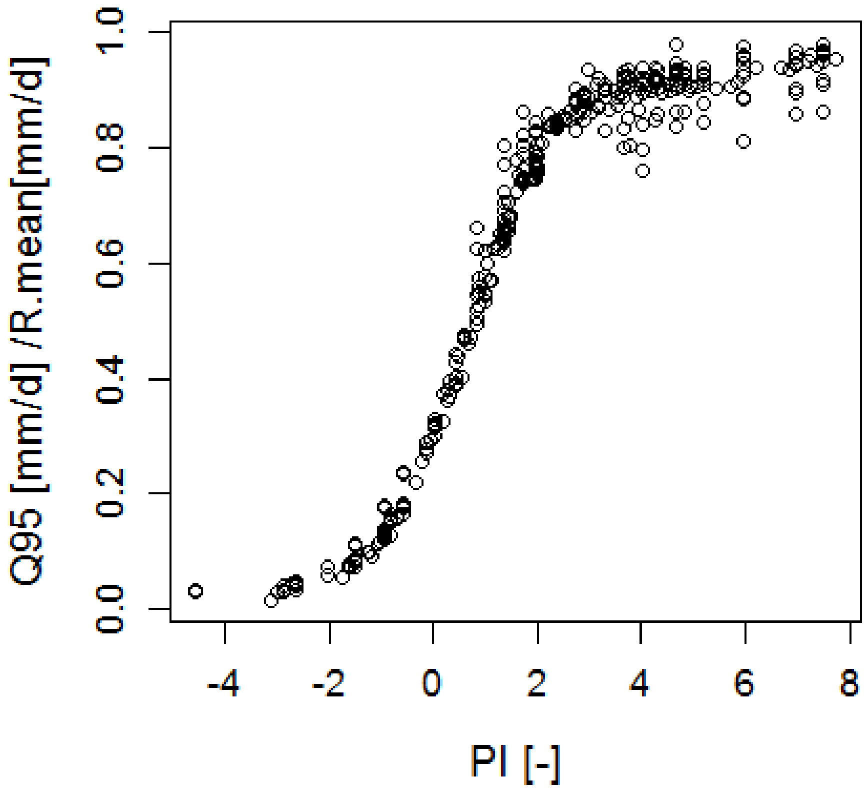




R2: fraction of variance of Q95/Q50 explained by physical parameters



Synthetic HGS models: Bedrock dynamics



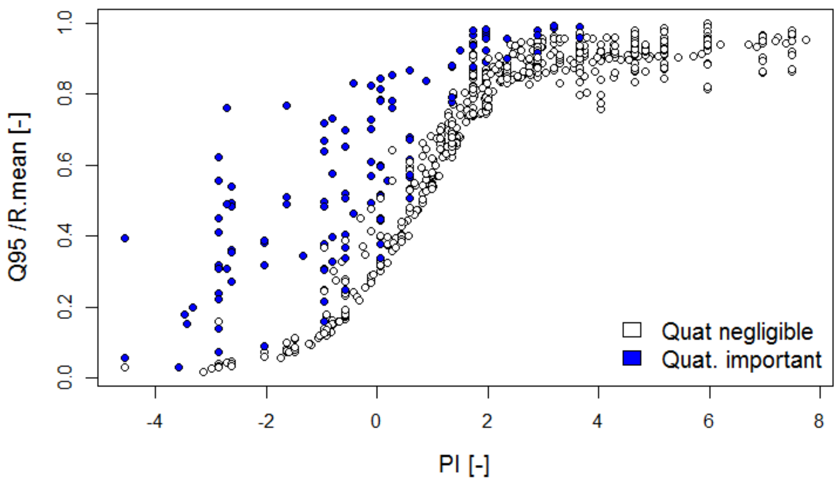
Bedrock models selection:

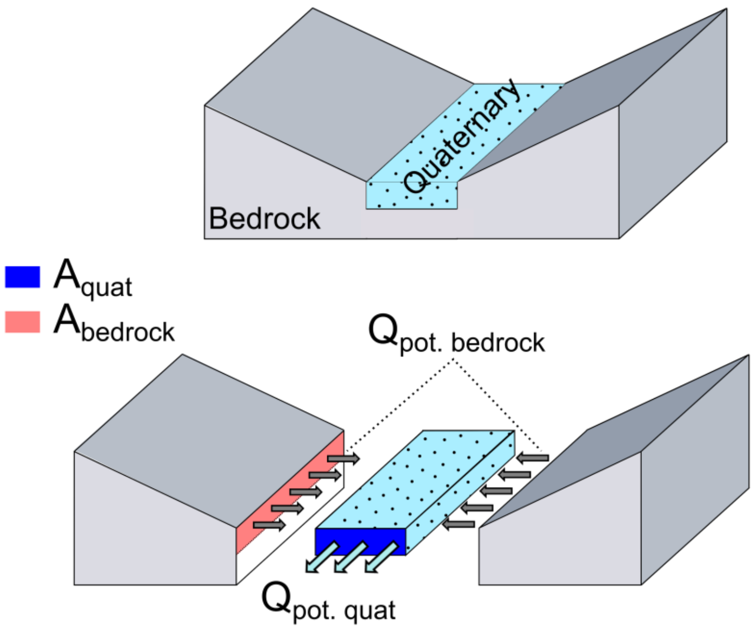
- More than 350 models composed of single hydrogeological unit
- Variation of: bedrock hydraulic conductivity and porosity, river slope, hillslope, valley width, aspect ratio, recharge time series

$$PI = \log \frac{K * HS^{3/2}}{R_{mean}}$$

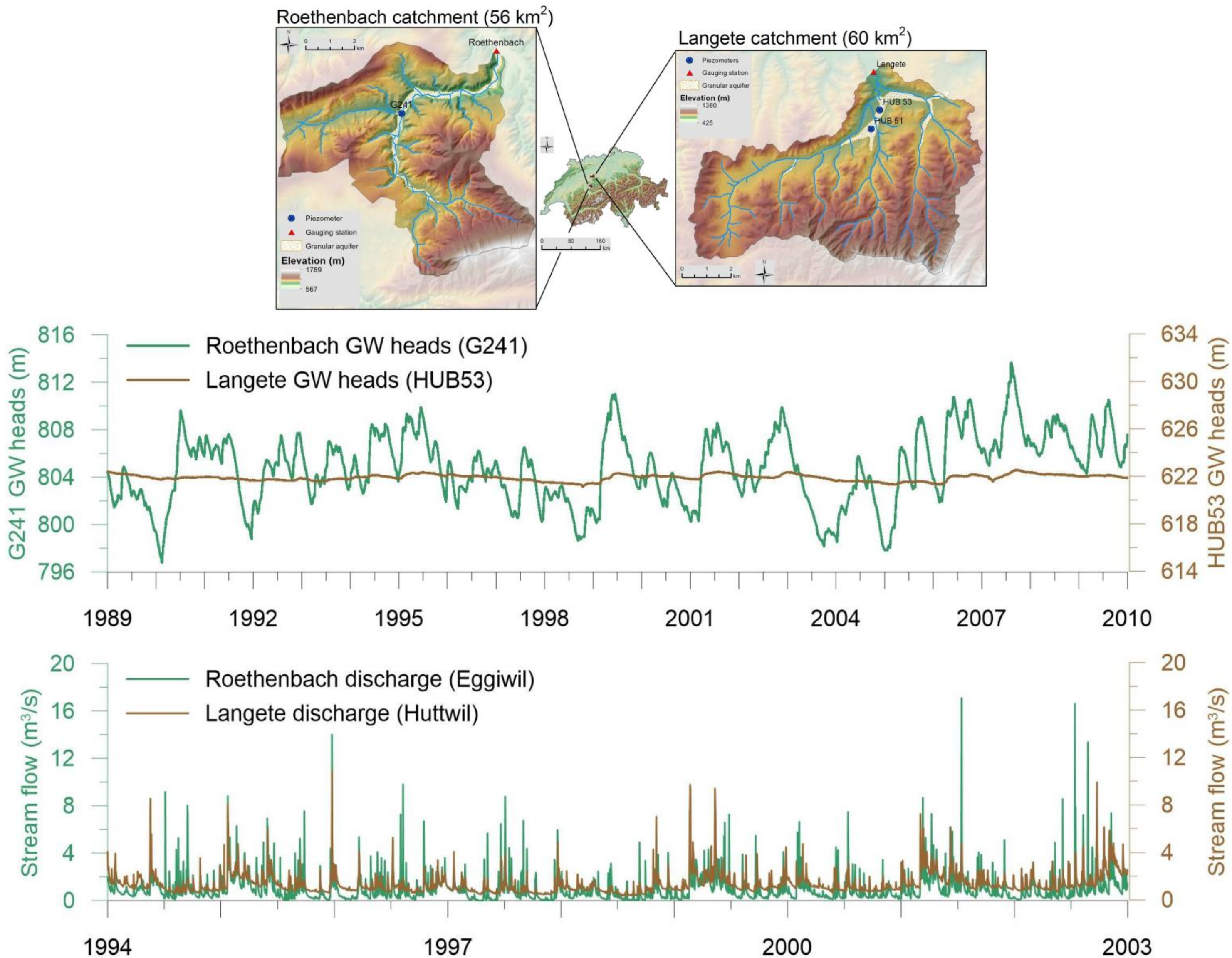
Synthetic HGS models:
role of quaternary valley aquifer

Bedrock + QUATERNARY

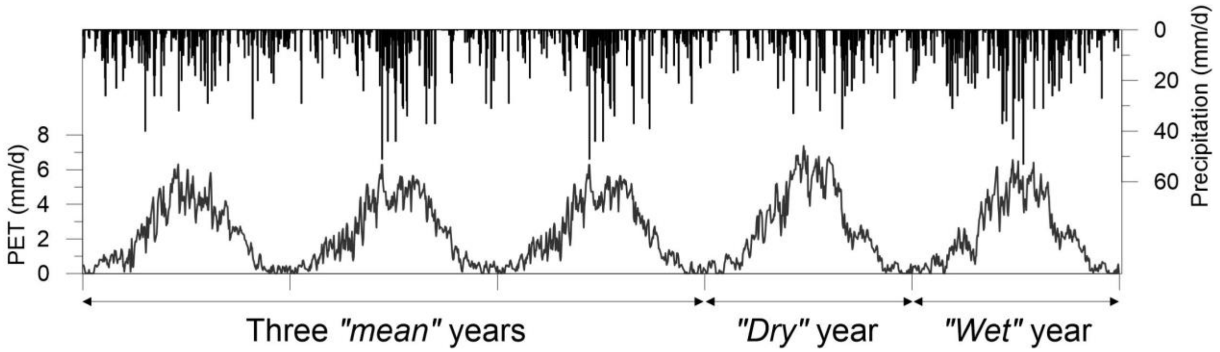


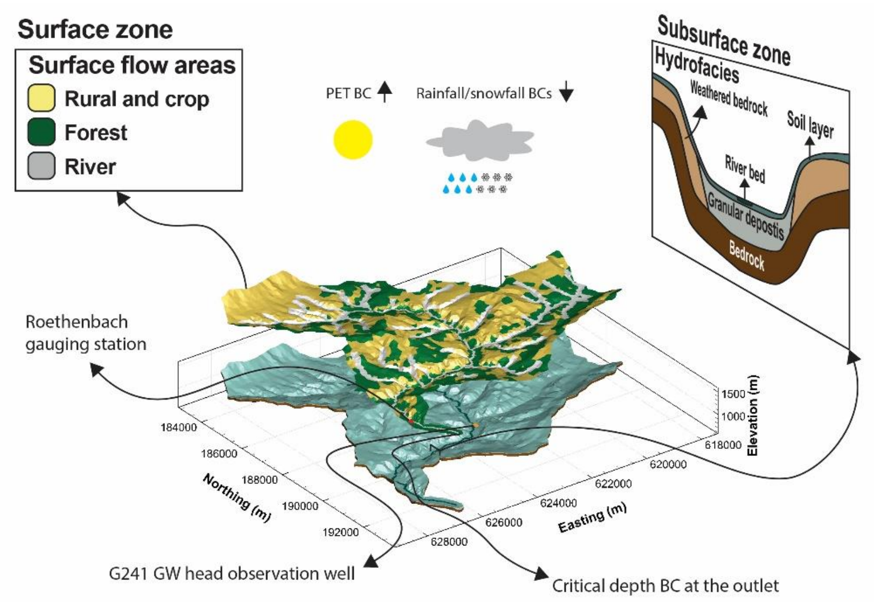


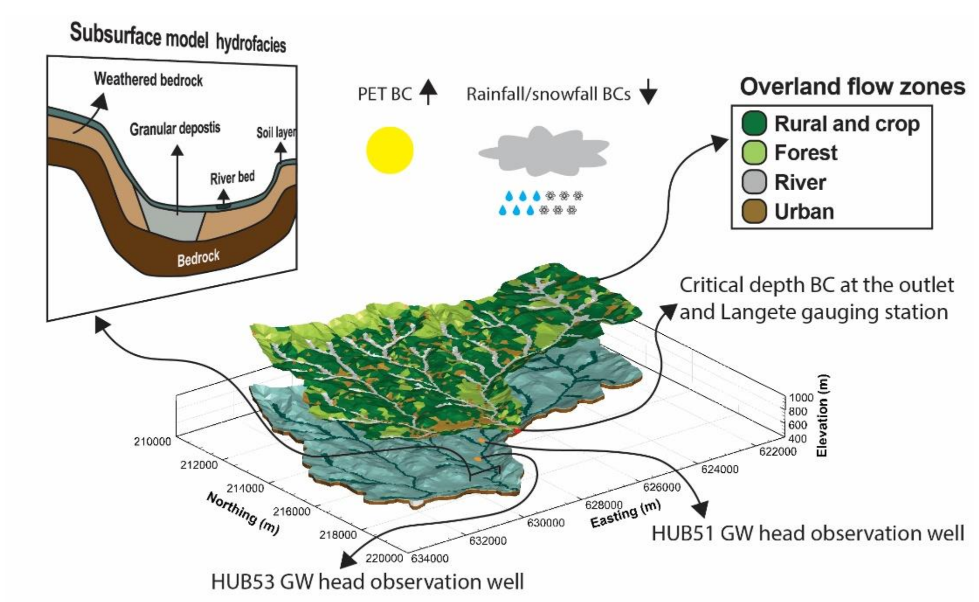
Detailed HGS models



Roethenbach and Langete models

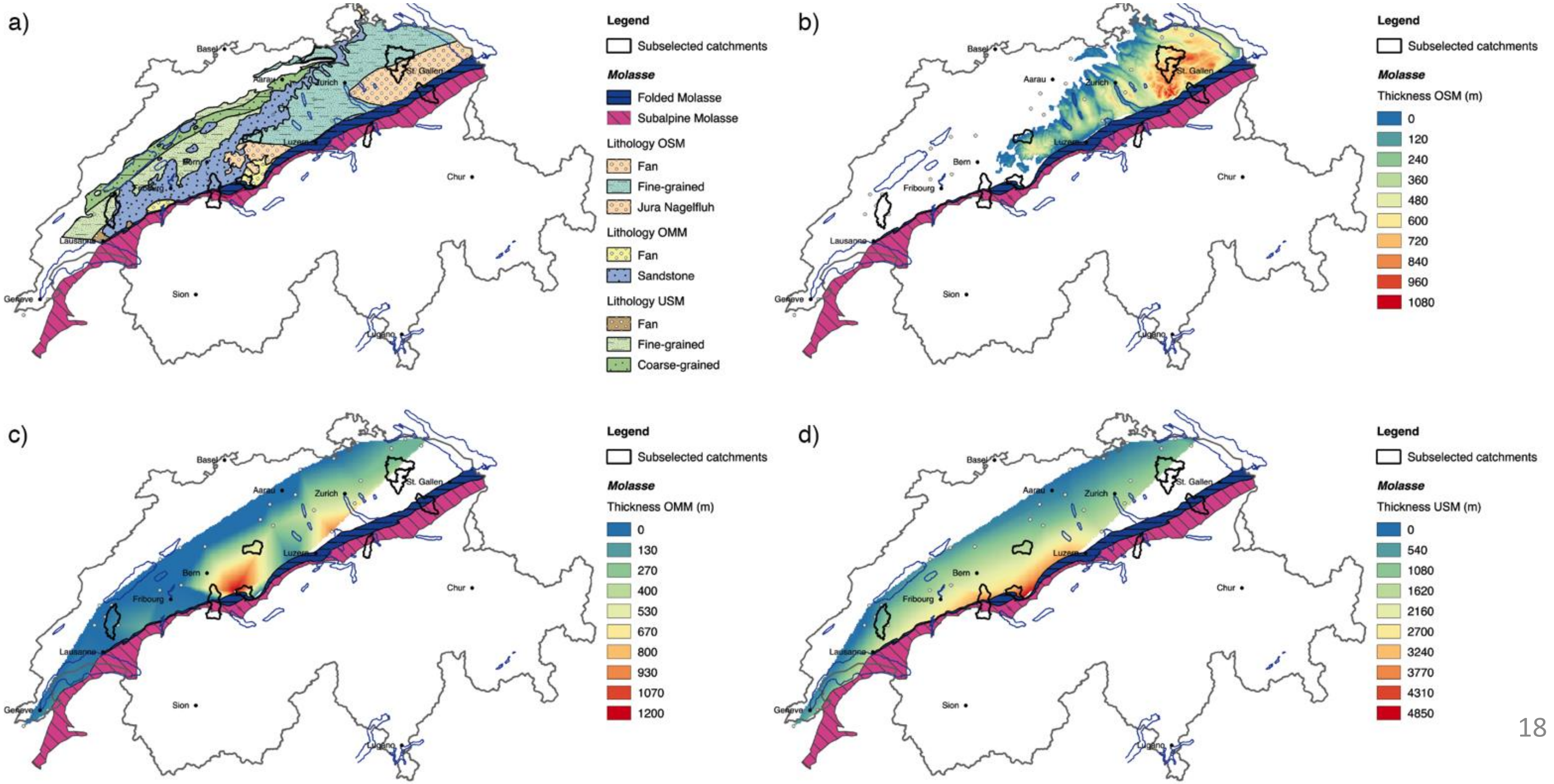




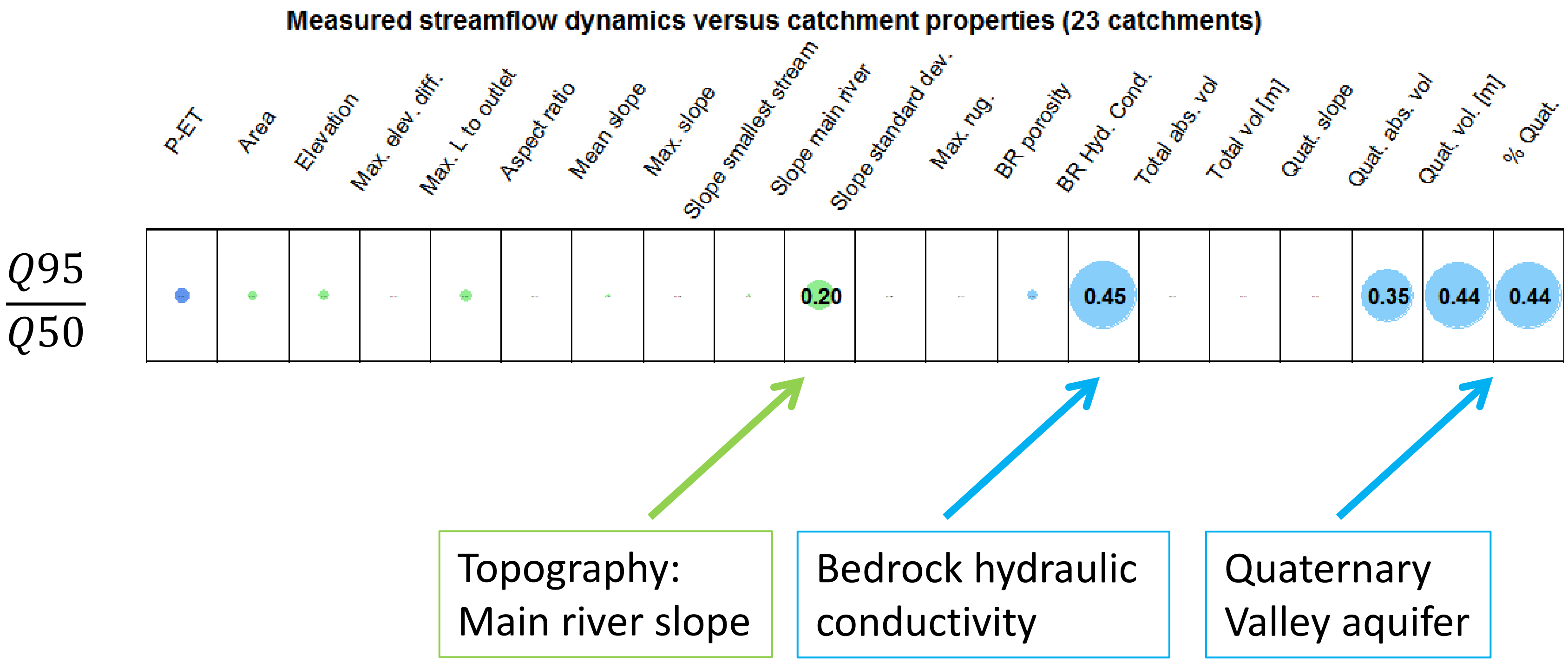


Productivity of the Molasse bedrock: Hydrogeological properties and 3D information

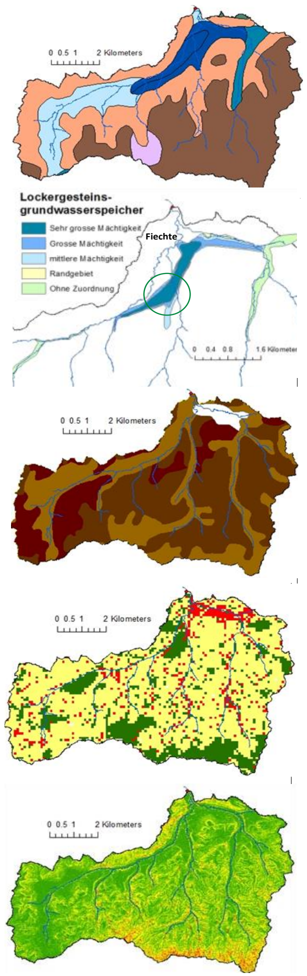
- Average K and P values for 5 lithologies
- Thickness maps: 3D information, e.g. for calculating total pore volume in a watershed
- Limitation: restricted database



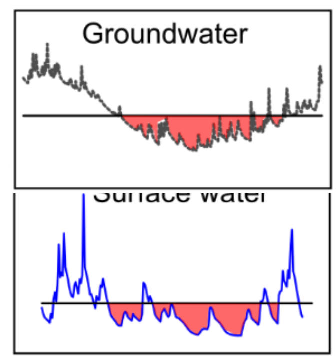
Validation with Swiss catchment database: controlling properties



How can vulnerable catchments be identified?



Infer sensitivity to droughts from catchment physical properties



If hydrographs are available:

- Modelling approaches can be employed
- In this project an Improved HBV model was developed to better account for low flow conditions
- Lessons learnt:
  - Take care using hydrograph data. Groundwater flowing under the gauging station has to be considered
  - Calibration of HBV has to be prediction specific

Main Conclusions

- Bedrock is an essential hydrogeological unit for catchment low-flow dynamics
- Quaternary alluvial deposits can also contribute significantly to low-flows
- Topography: the slope gradient of the contributing hydrogeological unit can influence low-flows significantly
- For low-flow studies, crucial to consider both GW and Q at the outlet
- Swiss catchment database: controlling physical properties are the same than for models
- Major uncertainties related to the properties of the bedrock