A method for the regional estimation of runoff separation parameters

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Outline:

- Introduction
- Regional analysis of the base flow index
- Estimation of runoff separation parameters
- Application in a regional water balance study
- Model performance
- Discussion and conclusions

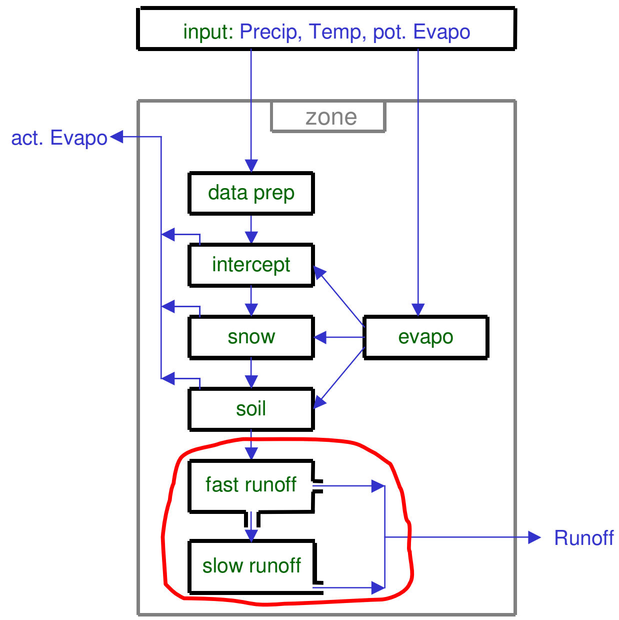
Introduction

What is this topic about?

Key processes for accurate Precip-Runoff modelling:

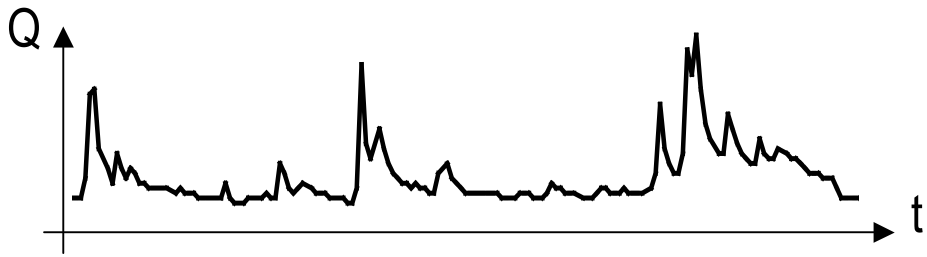
- Soil moisture accounting
- Runoff generation
- Runoff separation

focus only on this



Objective:
Estimate the basic characteristics of runoff separation from spatial data sets.

Introduction



surface flow ?
inter flow ?
base flow ?

→ Runoff separation determines the shape of the simulated hydrograph.

Traditional approach: **Calibration** with observed runoff.
Prediction in ungauged basins: Parameter **estimation.**

→ Important for:

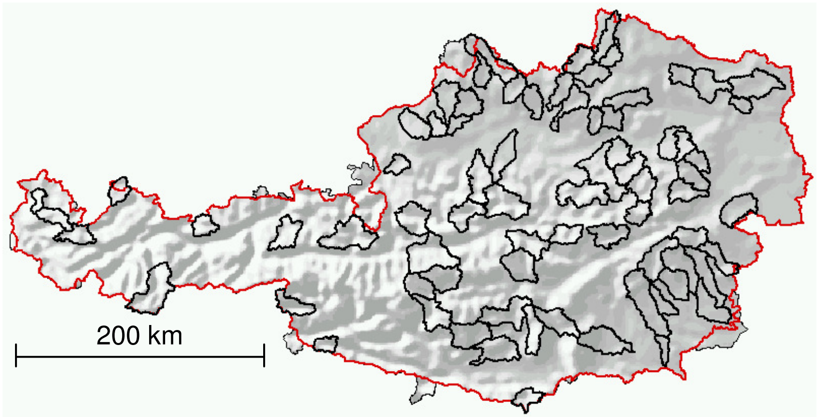
- Runoff simulations.
- Water balance modelling because of base flow.

Regional analysis of the base flow index

A basic characteristic of the hydrograph and a key variable for runoff separation is the **base flow index** (BFI).

BFI = base flow / total flow (long-term mean values)

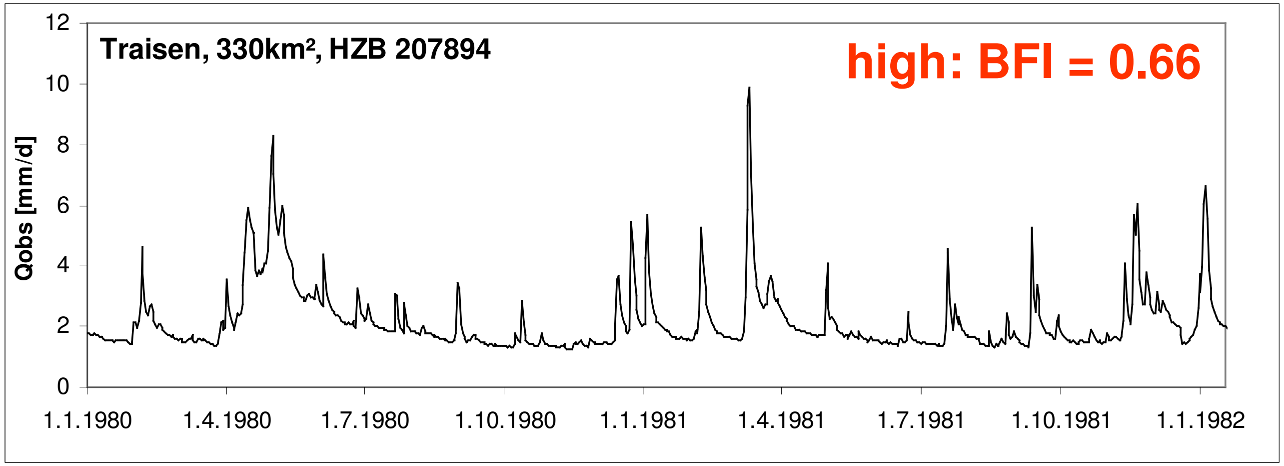
→ **Regional analysis:**
Study area: whole Austria.
75 unimpaired catchments.
Median size 350 km².
50 years with daily runoff data.

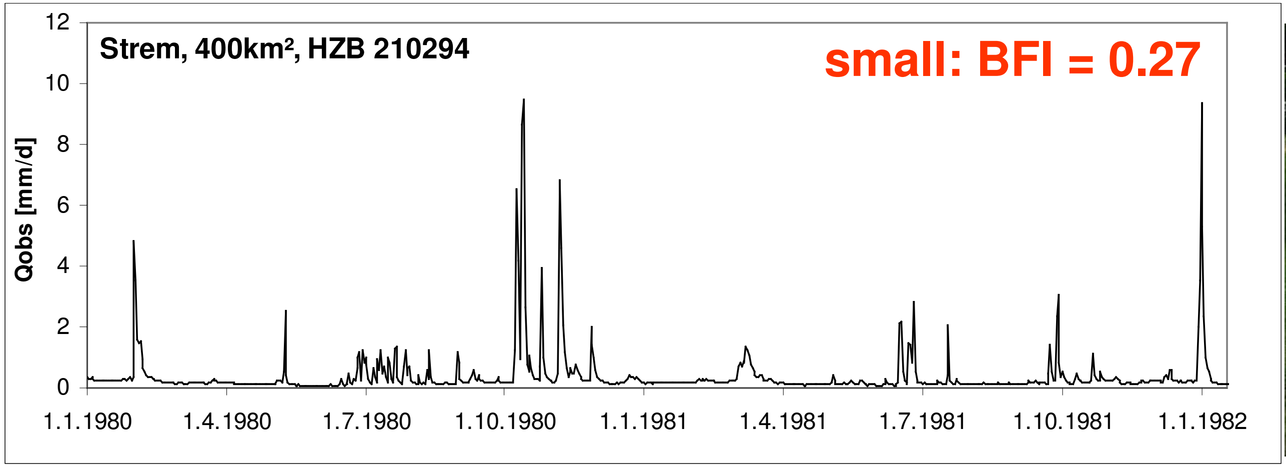


Compute BFI with the method of Bogena et al. (2005).

Regional analysis of the base flow index

Examples for BFI:





Regional analysis of the base flow index

Correlation between catchment attributes and BFI.

various attributes	r	land-use (4)	r	soil type (5)	r
area	0.20	Continuous urban	0.07	Cambisol low-land	-0.07
annual precipitation	-0.33	Discontinuous urban	0.03	Cambisol alpine	0.48
runoff-depth	-0.35	Sparsely vegetated	-0.33	Orthic Podsol	-0.01
river density (1)	-0.16	Agriculture	0.16	Orthic Rendzina	0.09
elevation	-0.15	Vineyards	0.19	Cambic Rendzina	-0.18
slope	-0.08	Grassland	-0.26	Planosol	-0.34
topographic index (2)	-0.02	Broad leaved forest	-0.08	Gleyic Luvisol	-0.04
hydrogeologic aquifers: (3)		Coniferous forest	0.38	Gleyic Podsol	-0.30
flow is mainly intergranular	0.07	Wetlands	-0.06	Chernozem	0.31
limited groundwater	-0.01	Open water bodies	-0.07	Non-calc. Lithosol	-0.31
karstifiable aquifers	-0.02	Glaciers	-0.29	Calcaric Lithosol	-0.17

→ Overall weak correlations, see also Merz and Blöschl (2004).

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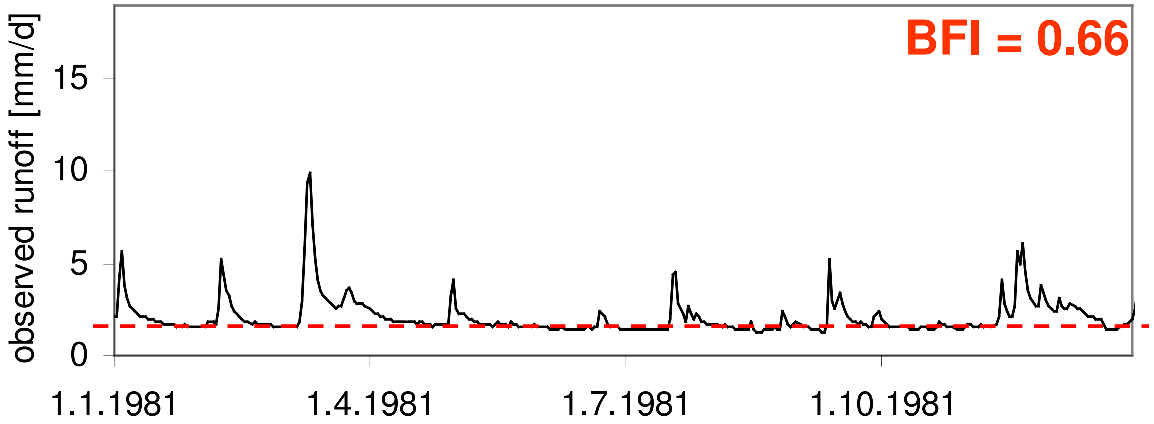
→ Some attributes show a signal.

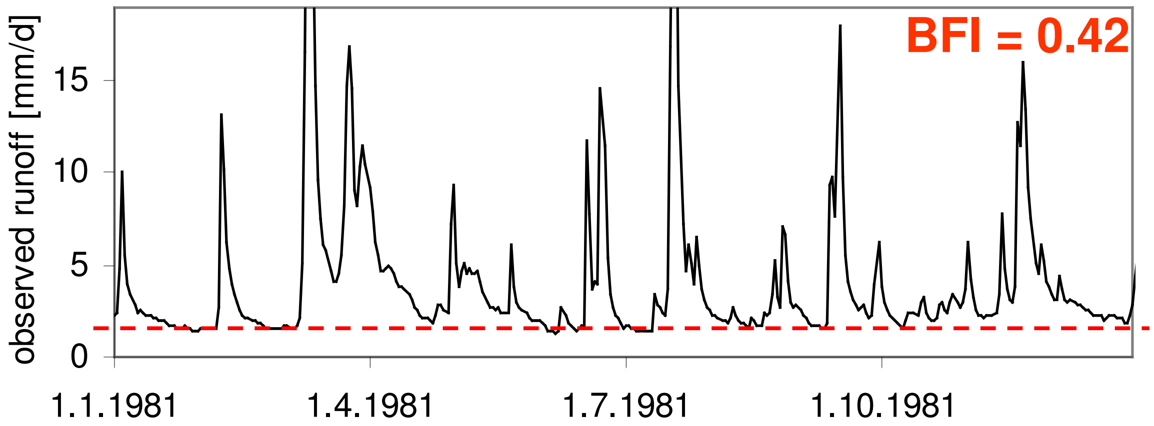
Estimation of runoff separation parameters

Same soil-type (Orthic Rendzina), different BFI, but ...

Traisen River, HZB 207894, 333.4 km², data 1959-2001, annual runoff 794 mm

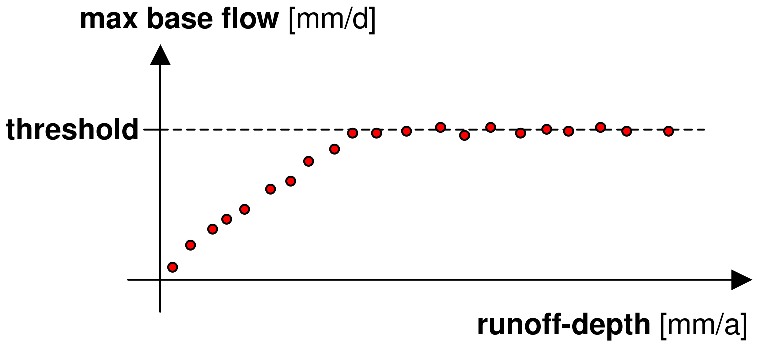


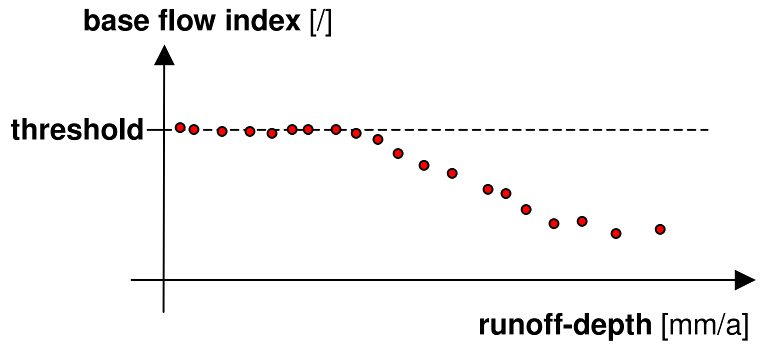
Ybbs River, HZB 207654, 506.9 km², data 1951-2001, annual runoff 1221 mm



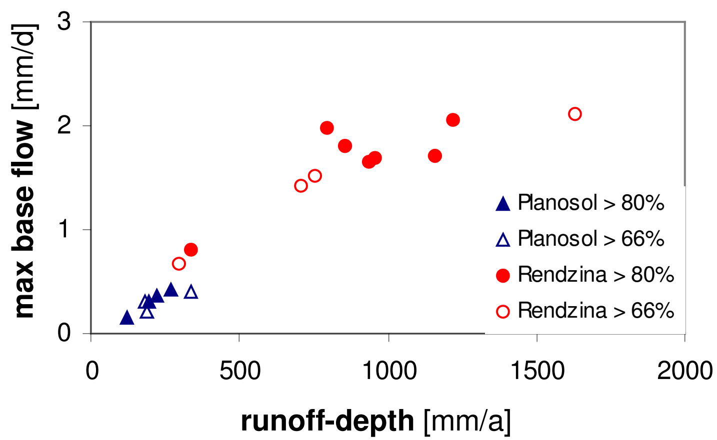
Estimation of runoff separation parameters

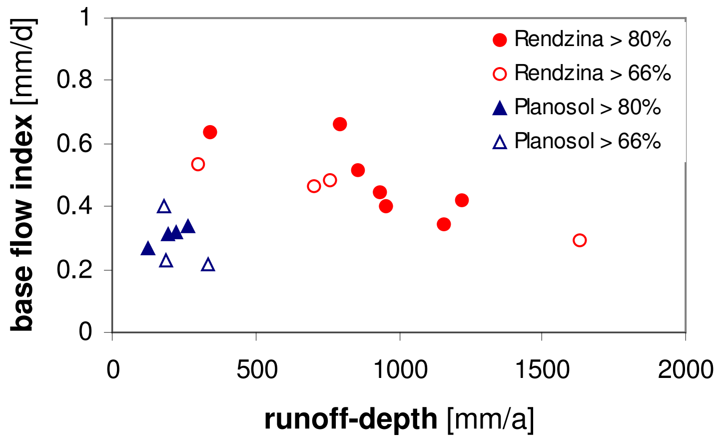
Theorethical relationship for catchments with a given soil-type:



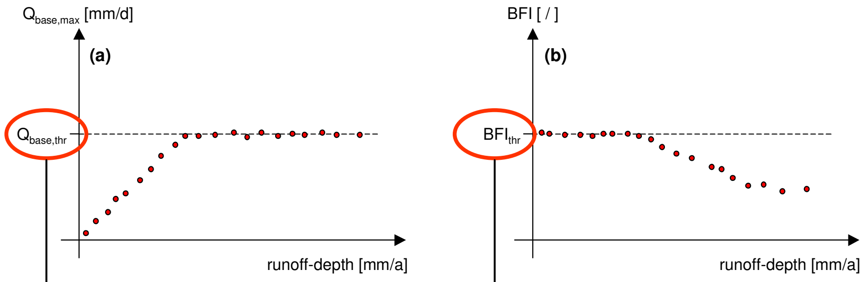


Data of real catchments:





Estimation of runoff separation parameters



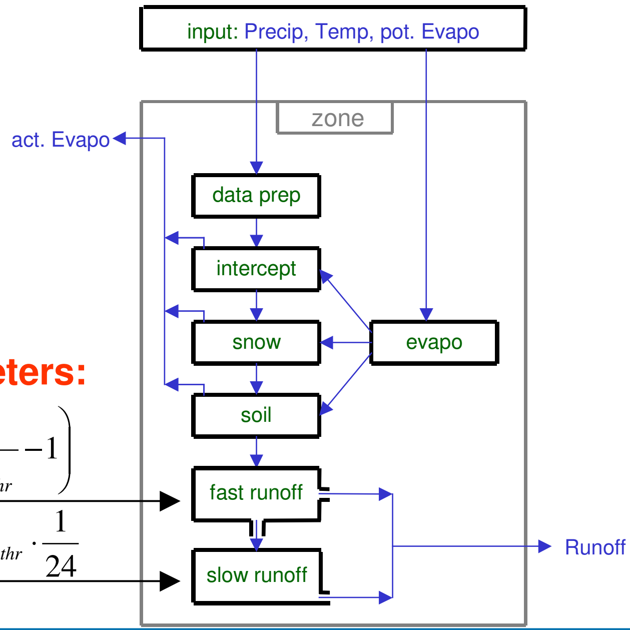
Estimation for each soil-type:

soil type	$Q_{base,thr}$ [mm/d]	BFI_{thr} [/]
Luvisol and Cambisol (low-land)	(2.5)	0.4
Orthic Podsol	1.25	0.45
Orthic Rendzina	2.0	0.65
Cambic Rendzina	2.5	0.65
Planosol	(2.5)	0.3
Gleyic Luvisol	(2.5)	0.4
Gleyic Podsol	1.5	(0.4)
Chernozem	(2.5)	0.8
Non-calcaric Lithosol	1.0	(0.3)
Calcaric Lithosol	(1.0)	(0.3)
Luvisol and Cambisol (alpine)	(2.5)	0.65

Transform to model parameters:

$$K_2 = K_1 \cdot \left(\frac{1}{BFI_{thr}} - 1 \right)$$

$$S_{\max} = K_3 \cdot Q_{base,thr} \cdot \frac{1}{24}$$

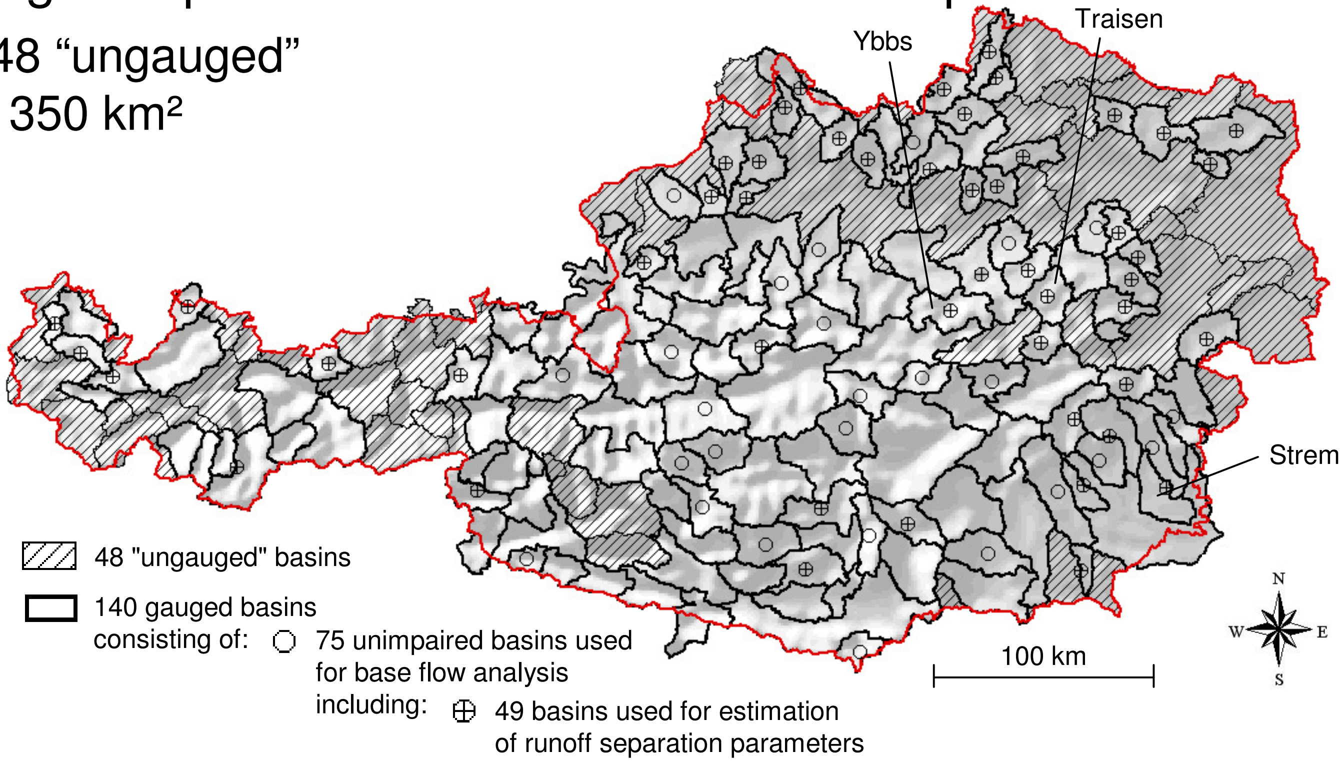


Application in a regional water balance study

Determine spatio-temporal water balance for the whole of Austria (84,000 km²), including ungauged basins.
→ Results published in the Hydrological Atlas of Austria.

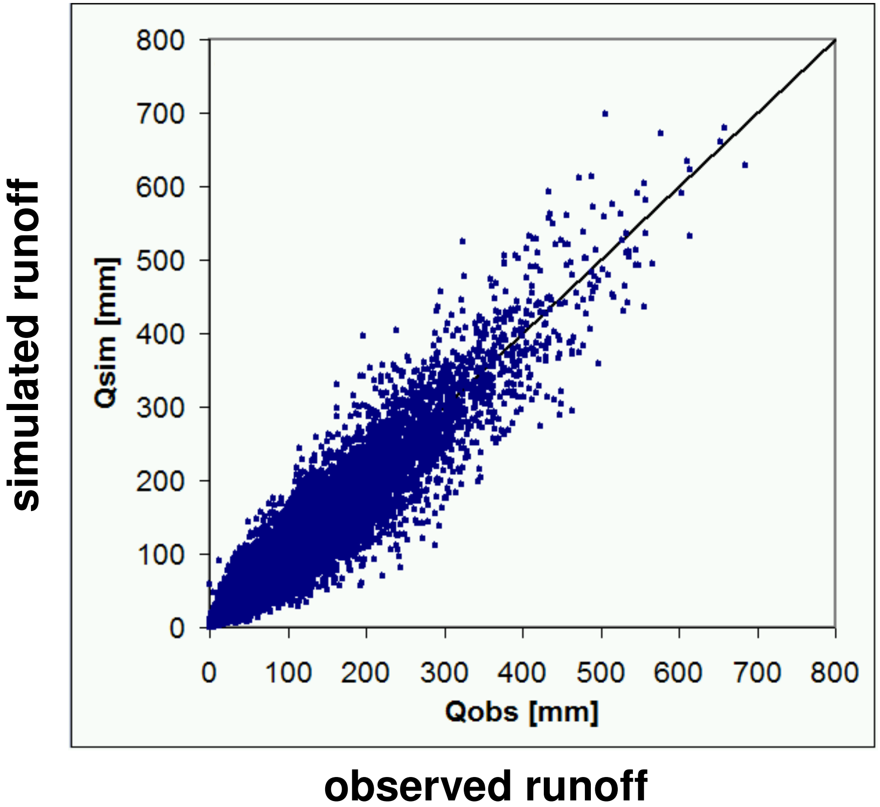
Conceptual, distributed (1x1 km), monthly water balance model.
Uses only regional parameter estimates based on spatial data sets.

188 basins, 48 “ungauged”
median area 350 km²



Model performance

Monthly runoff, 30 years, 140 gauges.



In many catchments snow processes are dominating.

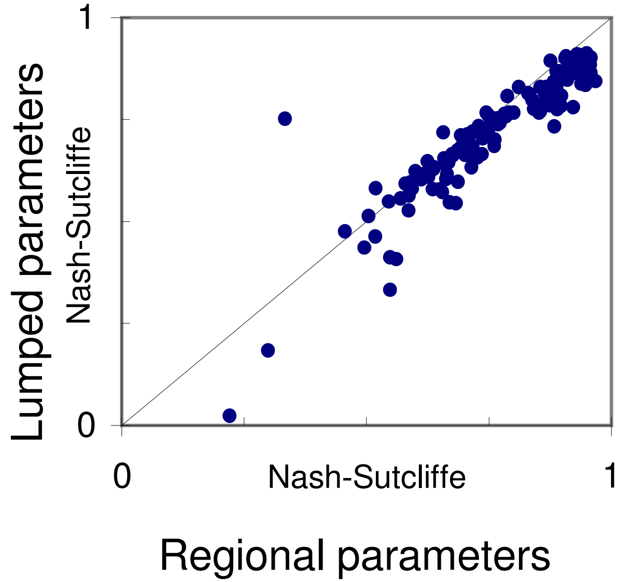
Model performance

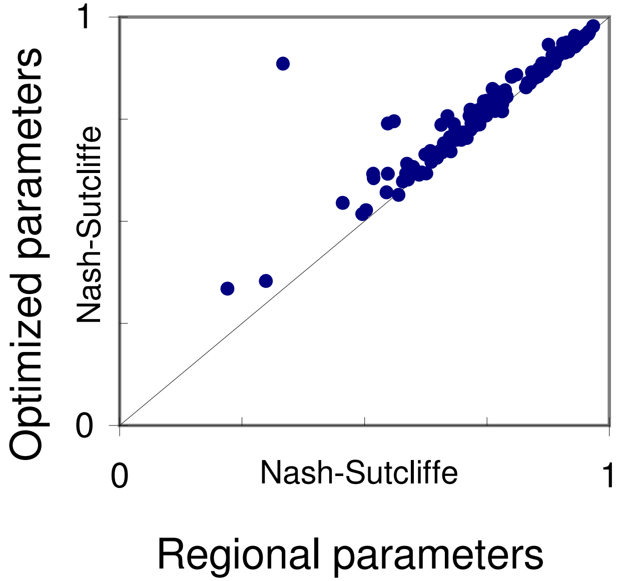
Nash-Sutcliffe measure (monthly runoff, 30 years, 140 basins)
different parameter sets:

Regional parameters: parameter estimates based on soil type
mean Nash-Sutcliffe = **0.74**

Lumped parameters: median of regional runoff separation parameters
mean Nash-Sutcliffe = **0.68**

Optimized parameters: local optimization of runoff separation parameters
mean Nash-Sutcliffe = **0.77**

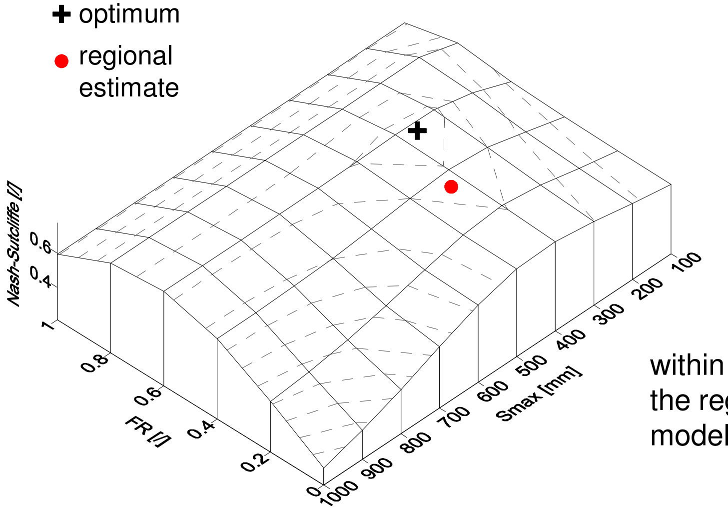




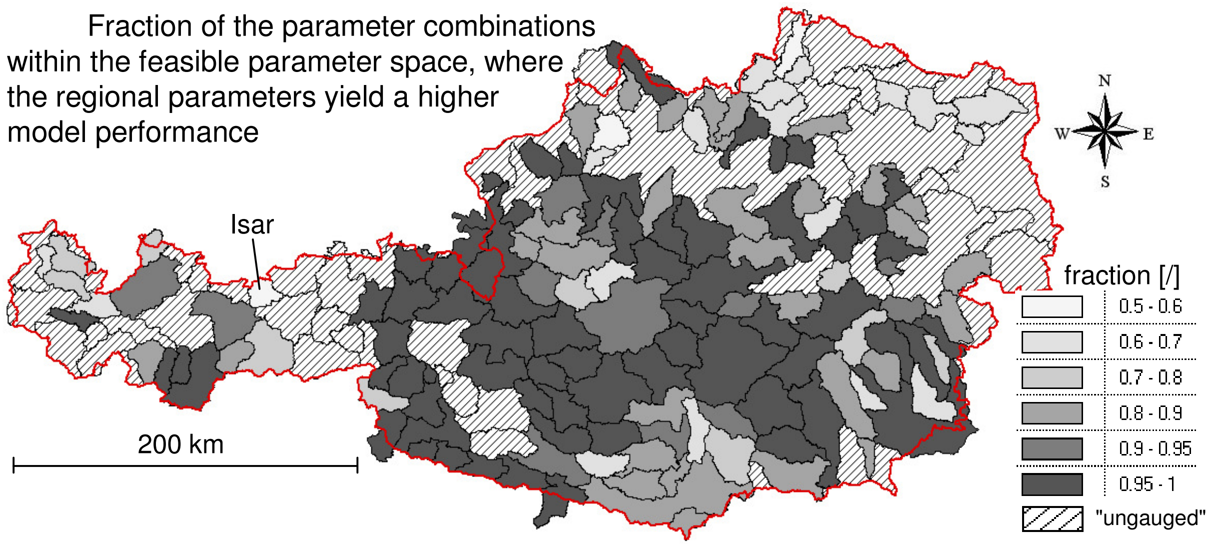
Model performance

A regional parameter estimation method is assumed to perform well, if the regional parameters perform better than most other parameter combinations within the feasible parameter space.

Objective function surface, Ybbs River

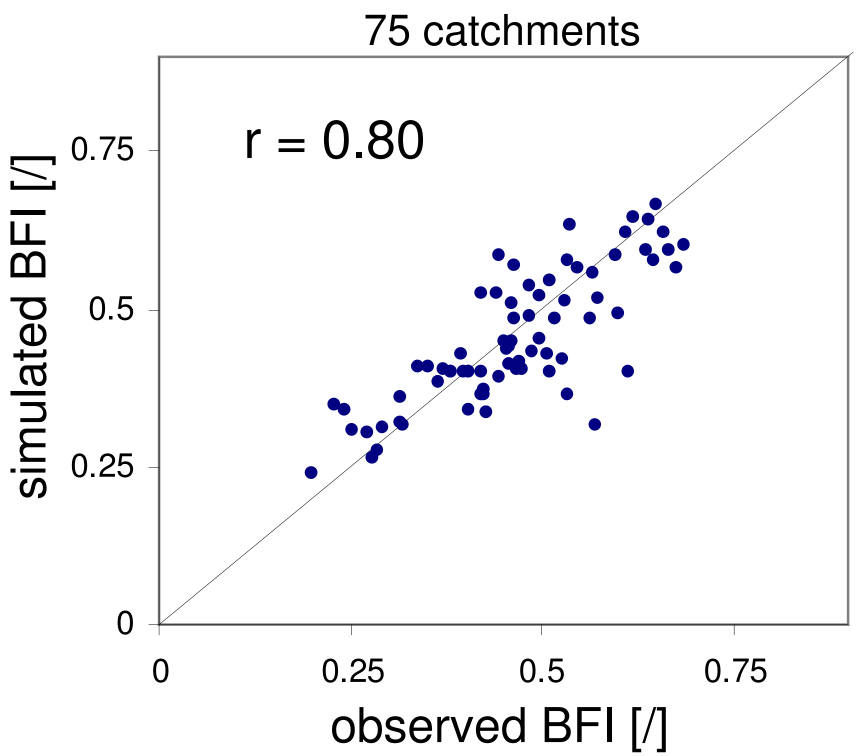


Fraction of the parameter combinations within the feasible parameter space, where the regional parameters yield a higher model performance



Model performance

The simulation results correlate with the observed BFI much better than in the initial regional analysis (max r was 0.48).



Discussion

• The results are less reliable in:
  - catchments dominated by Karst formations
  - dry low-land catchments

• The influence of land-use was not investigated in this study.
However, this is in accordance e.g. with the base flow study of Haberlandt et al. (2001).

• Some soil-types are only found in limited areas. In such a case the soil-type may function to delimit a region with specific conditions (e.g. meteorological forcing may be the first order control). However, the soil-type itself may be the very result of these conditions.

Conclusions

• The **simple method** for the estimation of runoff separation parameters **performs well** compared to optimization.

• **Threshold processes** complicate to find universal relationships between model parameters and catchment attributes at the regional scale.

• If it is not accounted for these **threshold processes** then the relationship between model parameters and catchment attributes (in this case soil-type) will be **cloud**ed.

• Even with a monthly model it is possible to simulate the basic characteristics of runoff separation.

Thank you for your attention!