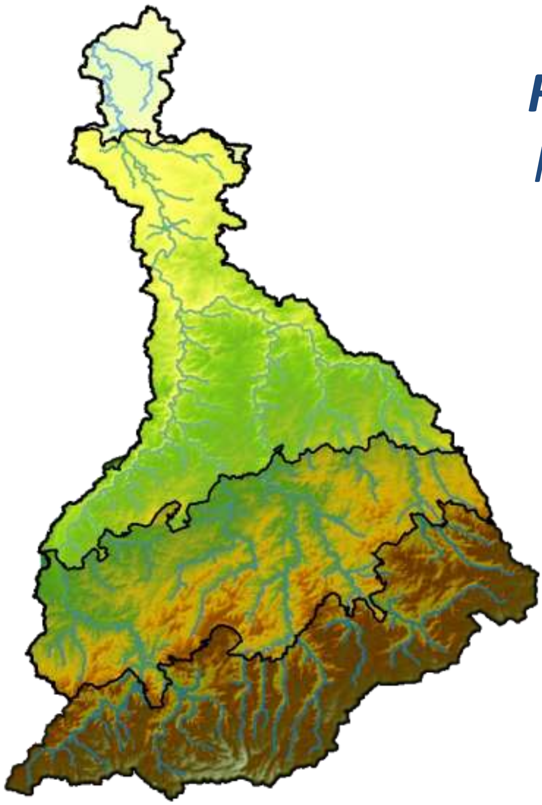
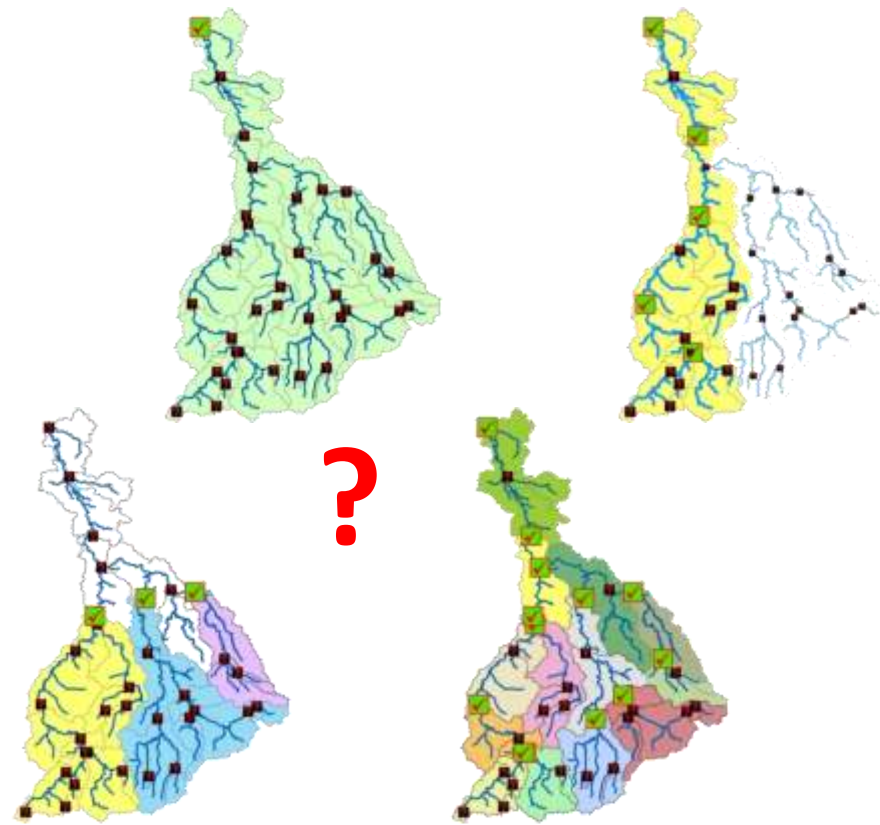
Comparing different model calibration strategies for improved representation of landscape conditions in SWAT at the example of a large heterogeneous catchment



Felix Witing
Martin Volk



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Soil & Water Assessment Tool SWAT

TECHNISCHE UNIVERSITÄT DRESDEN

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

Problem of equifinality in inverse model calibration

- Smaller, relative uniform catchment

Input ← MODEL ← Output

- Larger, heterogeneous catchment

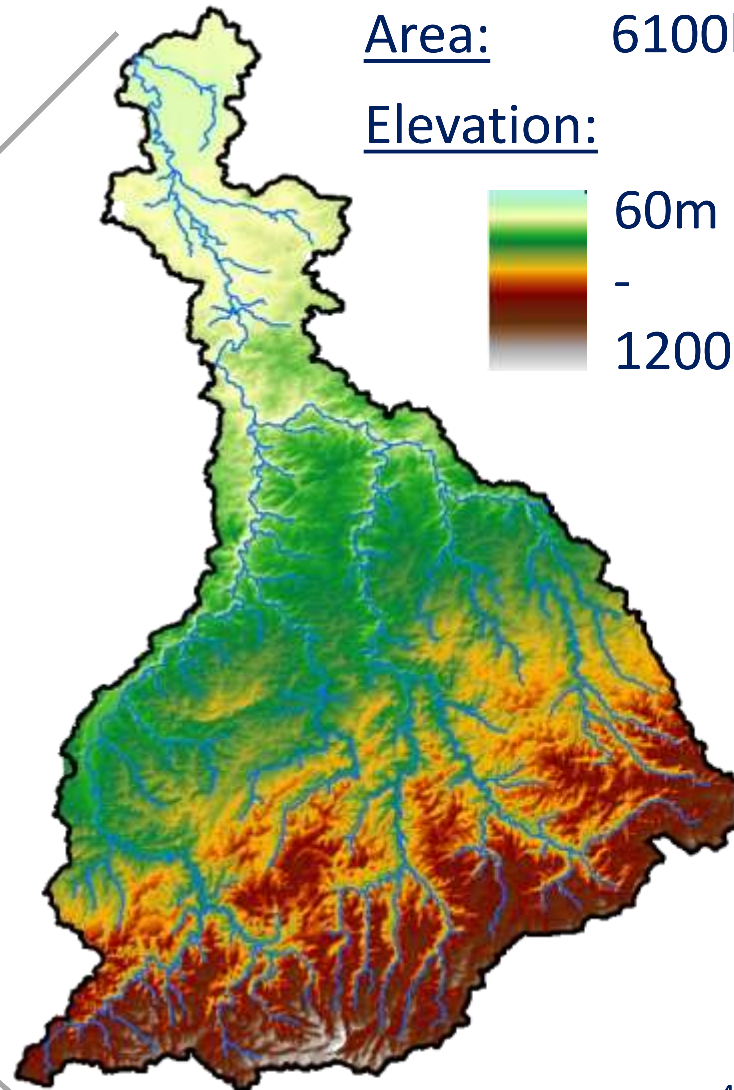
Input ← MODEL ← Output

How to calibrate a model to achieve a suitable representation of the different landscape conditions in the catchment and thereby decrease the parameter uncertainty?

- Investigate the influence of different model calibration strategies regarding:
  - Number of sites used for calibration (what data is available?)
  - Location of these sites in aspect of basin-internal landscapes
  - Type of calibration

- Optimization of the calibration procedure regarding:
  - representation of the different landscape conditions
  - Calibration result and parameter uncertainties
  - Amount of work and computing time

Mulde watershed

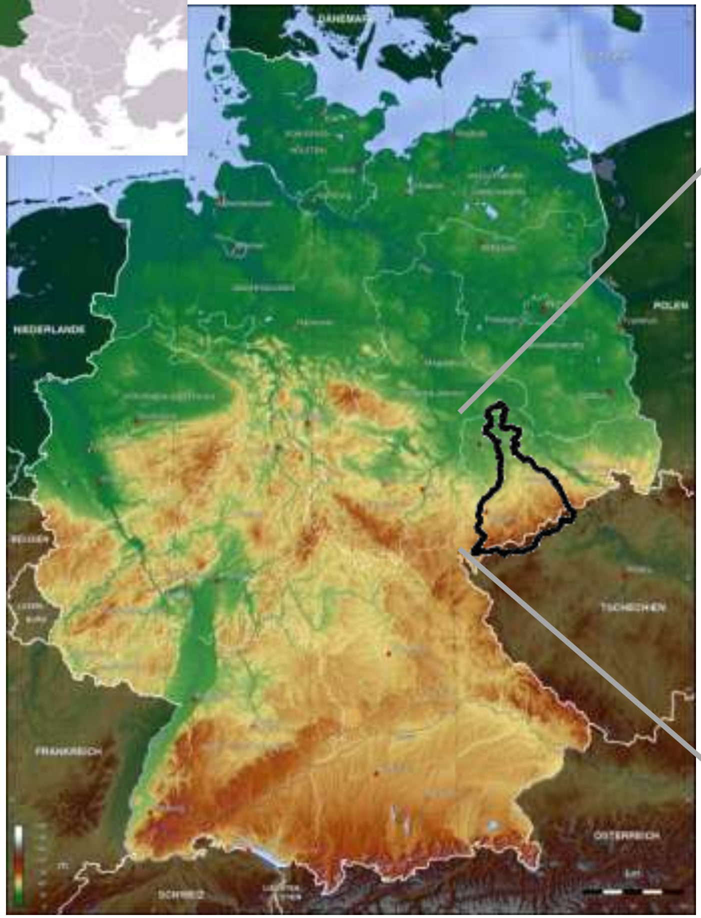


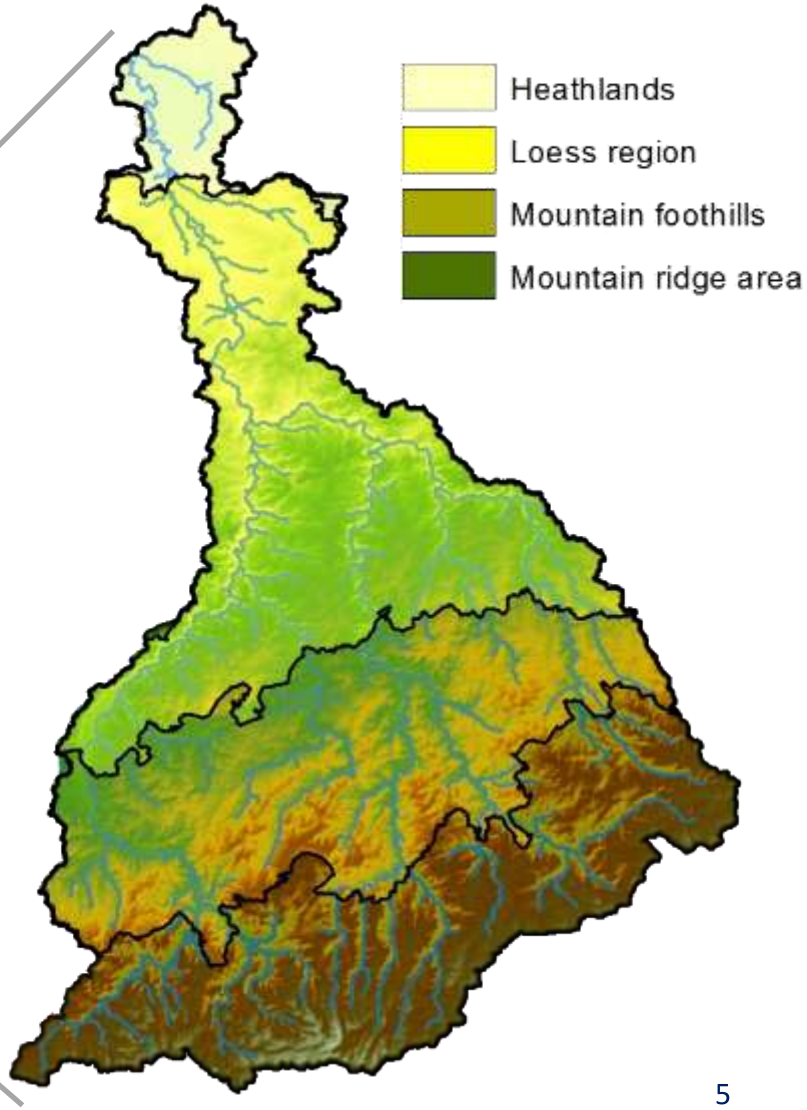
Area: 6100km²

Elevation:

60m
-
1200m

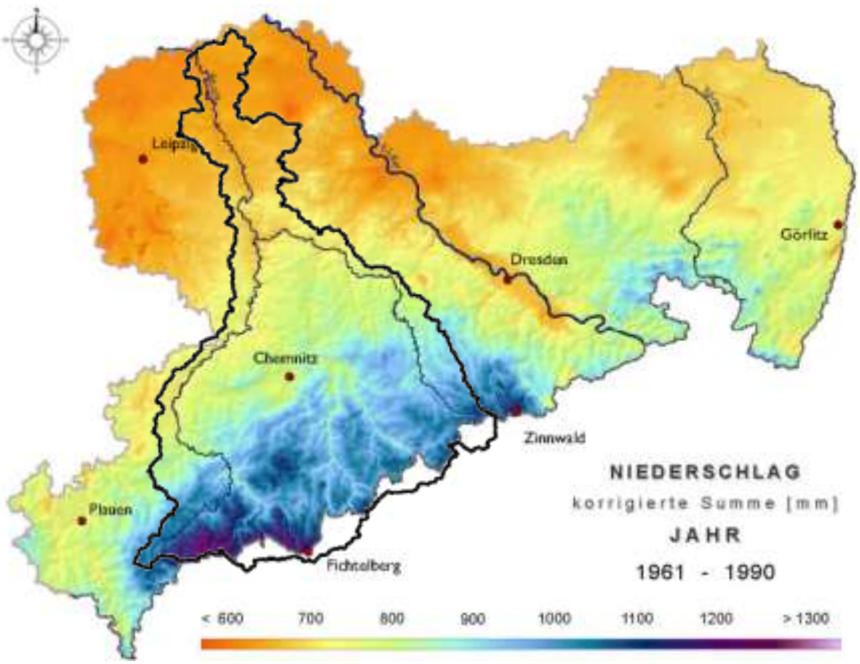
Mulde watershed





Watershed characteristics

Precipitation

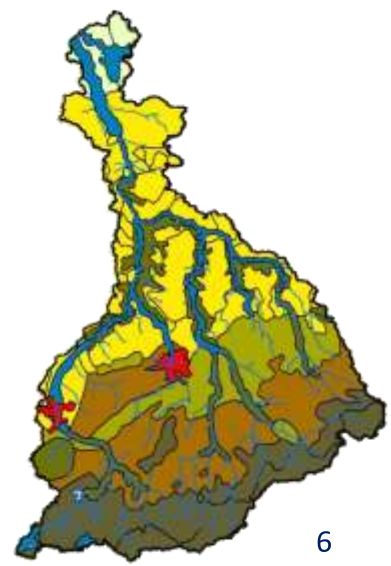


Land use

- Urban/Industrial
- Agricultural
- Forest
- Pasture/Grasslands
- Shrubs
- Water Bodies

Soils

- Soils in river valleys
- Sandy soils in undulating lowlands
- Soils in loess areas
- Soils from rocks mixed with loess
- Soils from redeposited rock material
- Soils from silty slates
- Mountain/hill soils from solid rocks
- Sealed areas in larger cities
- Surface water



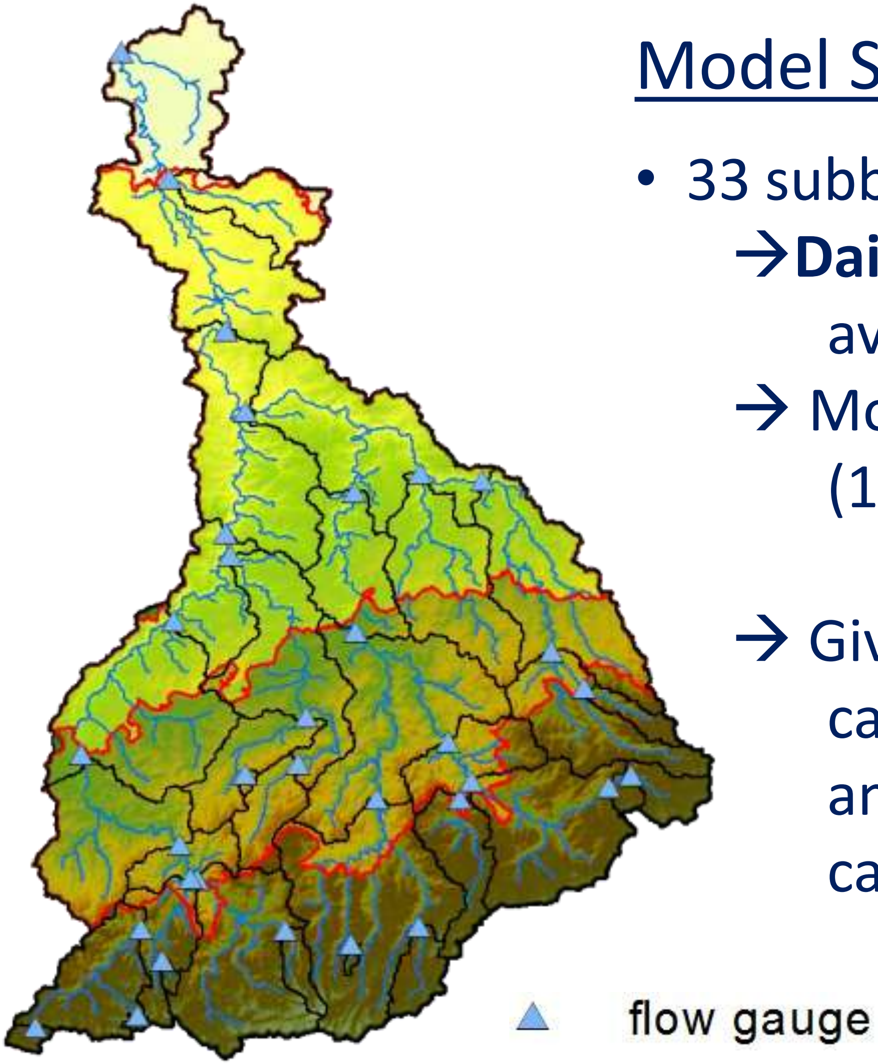
Model Setup

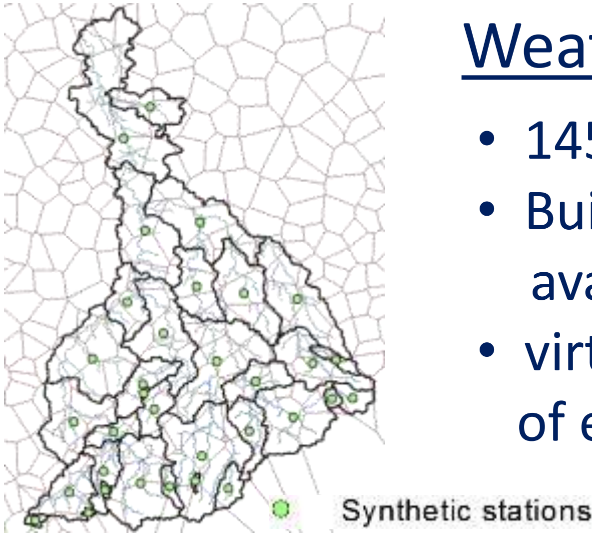
- 33 subbasins

  → **Daily discharge data** (1974-2009) available **for all** of them!!

  → Monthly sediment and nutrient data (1999-2009) available for 14 sites

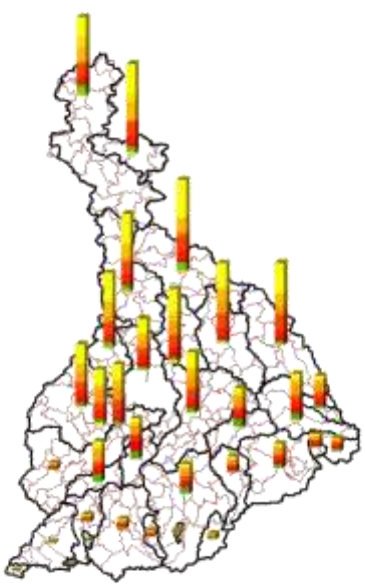
  → Gives us the possibility to verify the calibration result in every sub-basin and to be very flexible in how to calibrate in general





Weather Data

- 145 precipitation stations, 14 climate stations
- Built Thiessen polygons for every day, depending on available stations
- virtual station for every sub-basin, weighted by area of each polygon inside a sub-basin



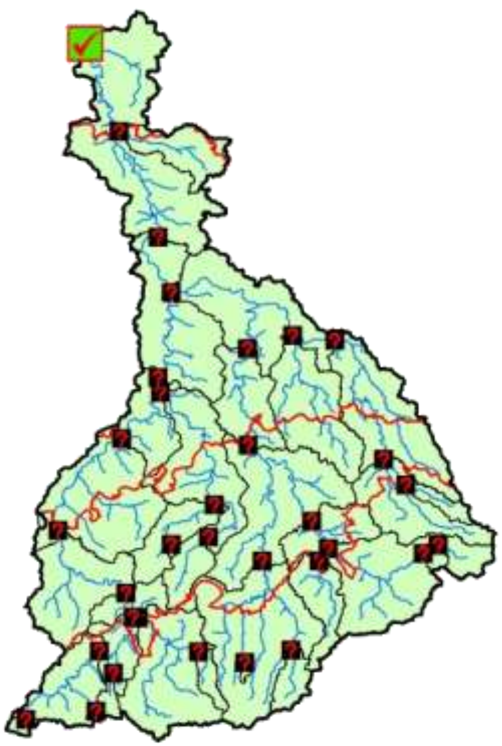
Management

- Yearly statistics about cultivation areas of communities: 66 differentiated crops
- crop statistics of 9 most important for every sub basin + typical management for every crop

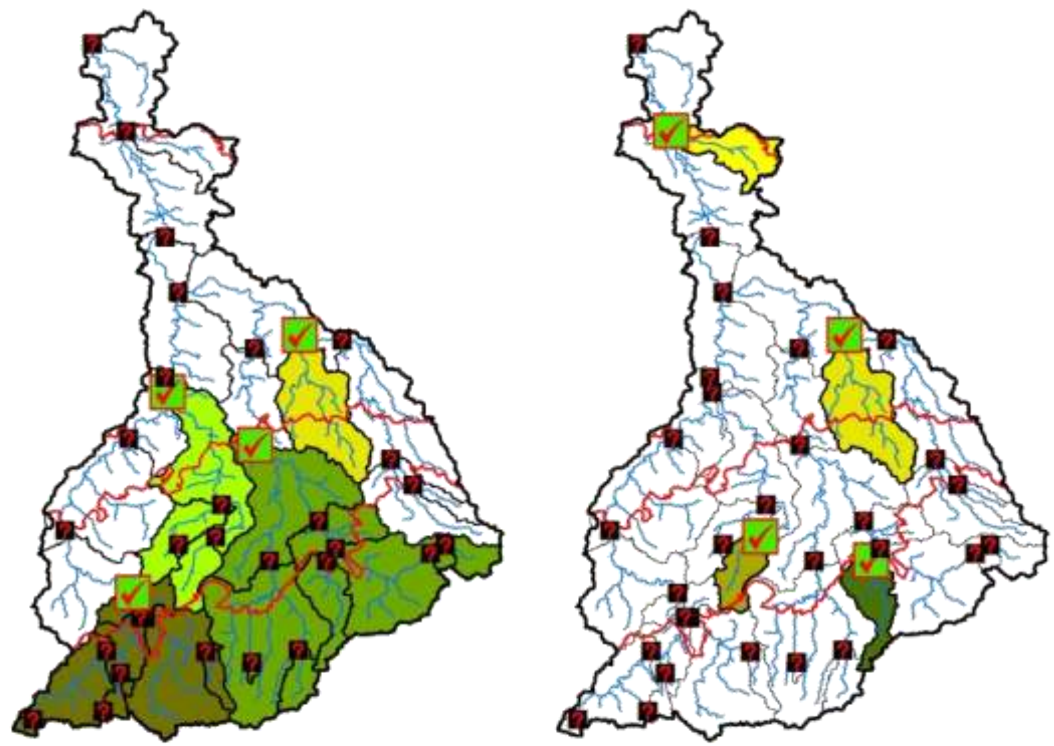
→ To minimize effect of management and weather data quality on calibration result

"conventional" calibration techniques

→ Single-site calibration

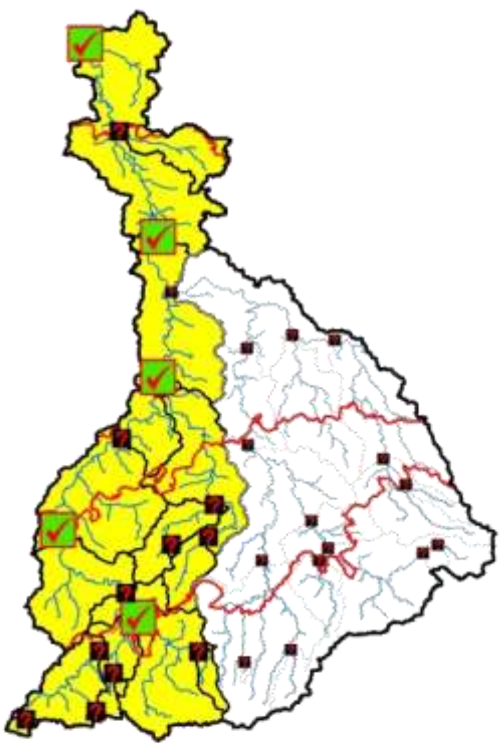


→ Multi-site calibration
(mutually independent gauges)

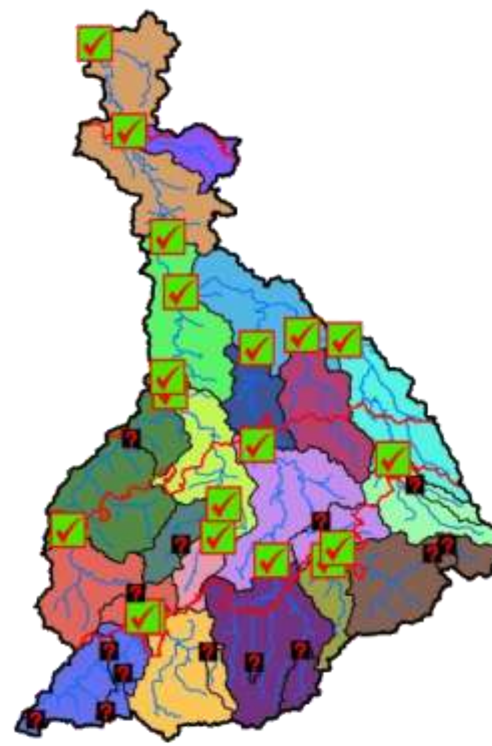


"unconventional" calibration techniques

→ Multi-site calibration (hydrological connected gauges)



→ Separate model for each calibration site



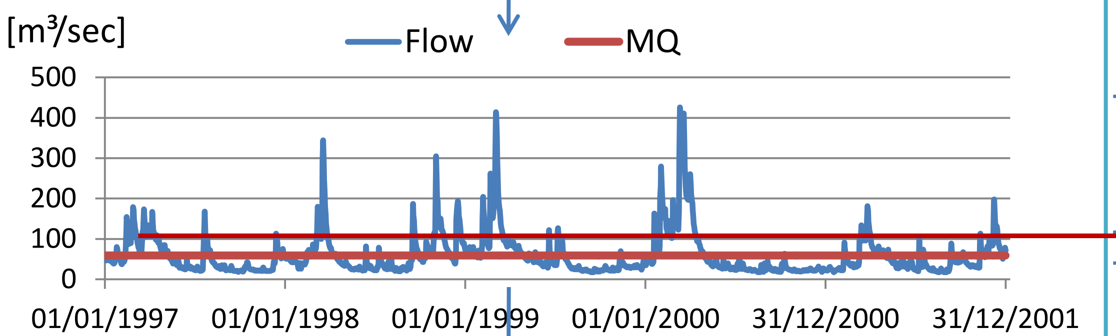



Subbasin → Sensitive parameters

1, 2, 3, 4 … n → 10, 10, 10, 10 … 10

One parameter set (21) for all calibrations

Objective function definition



Sequential Uncertainty Fitting (SUFI-2) Swat-Cup

Adjustment of sensitive parameters : |t-stat| > 1

d-factor<1 Stop

= avg. width of 95PPU / std. dev. of measurements

Sensitivity analysis (van Griensven et al. 2006)

„multi-component“ assignment of sum square error:

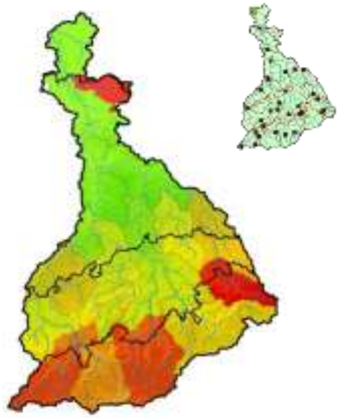
$$g = w_{HQ}\sum_{i=1}^{n_1}(Qm-Qs)_i^2 + w_{LQ}\sum_{i=1}^{n_1}(Qm-Qs)_i^2$$

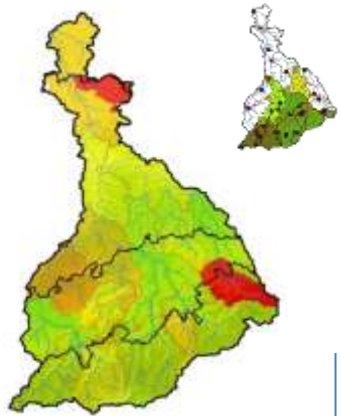
$$w_{HQ} = 1/n_{HQ}\sigma_{HQ}^2$$

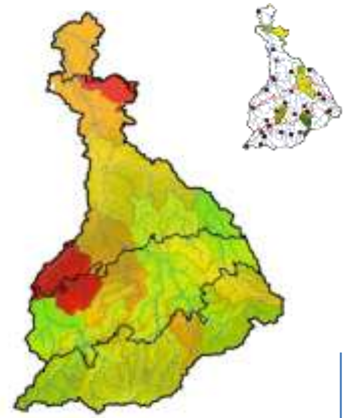
$$w_{LQ} = 1/n_{LQ}\sigma_{LQ}^2$$

Daily time step!

Calibration (1997-2001)







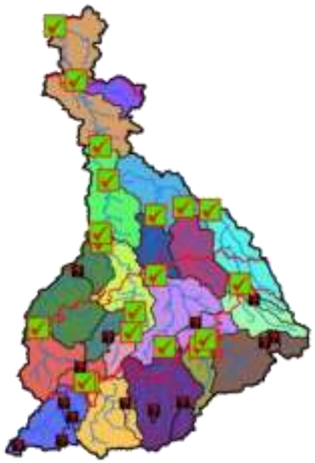
Nash- Sutcliffe

- -1.50 - 0.00
- 0.00 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.40
- 0.40 - 0.50
- 0.50 - 0.60
- 0.60 - 0.70
- 0.70 - 0.80
- 0.80 - 0.90
- 0.90 - 1.00

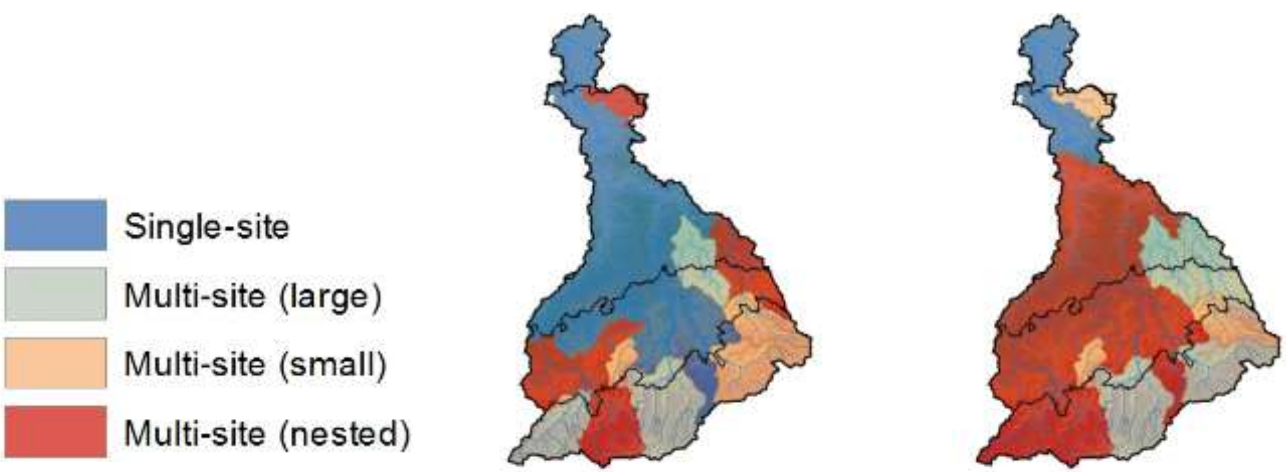
	NSE	Valid	NSE	Valid	NSE	Valid	NSE	Valid
Outlet	0.74	0.65	0.37	0.36	0.28	0.27	0.64	0.57
Loess Region	0.58	0.66	0.39	0.58	0.32	0.49	0.58	0.74
Loess-Foothills	0.42	0.29	0.45	0.64	0.40	0.56	0.52	0.65
Foothills	0.45	0.10	0.60	0.61	0.56	0.59	0.65	0.67
Mountain Ridge	0.19	-0.49	0.52	0.46	0.54	0.57	0.57	0.58

Validation (2003-2005)

Separate Model for each calibration site



Best parameter set: Calibration period Validation period



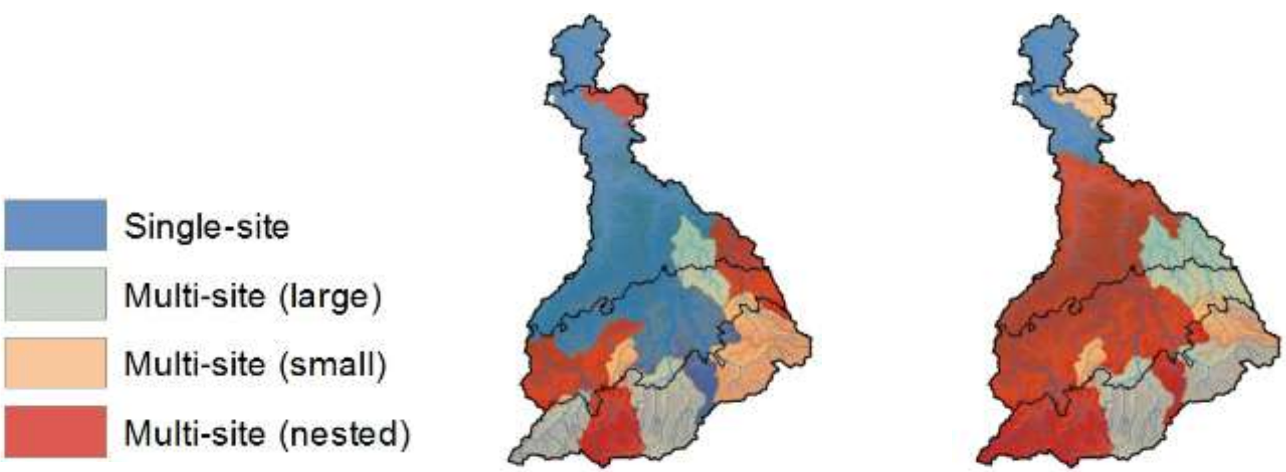
Potential in calibrating each site separately:

Nash Sutcliffe	Maximum	Validation	**Separate Calibration**	**Validation**
Sub5 (Cross section)	0.62	0.65	0.71	0.69
Sub17 (Foreland)	0.55	0.52	0.61	0.58
Sub22 (Mtn. Ridge)	0.52	0.48	0.68	0.65

Calibration period

Validation period

Best parameter set:



Conclusion

1. It is important to ensure that all (hydrological varying) landscapes are included in calibration process

2. Single-site calibration at the basin outlet turned out to be insufficient for a heterogeneous watershed

3. Using a separate model for different sites has a great potential but also amount of work

Outlook

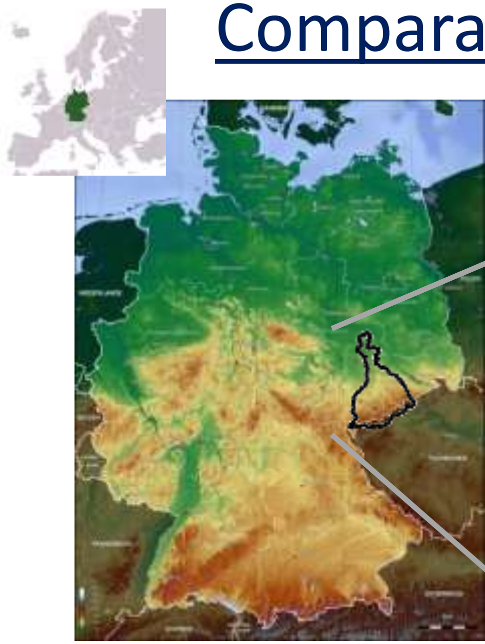
1. Strengthen of the calibration procedure by using multiple variables (NO_3, sediment..)

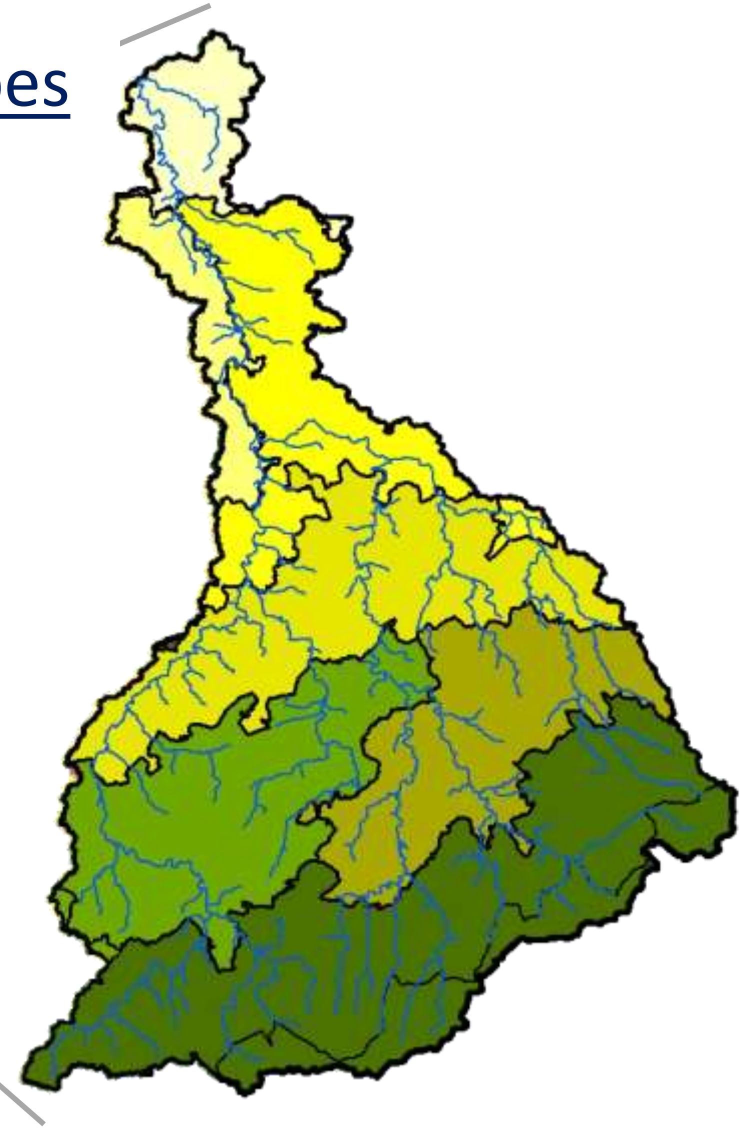
2. Investigate the possibilities of transferring separate-site calibrations to other sub basins in the same landscape

3. Validate the results in smaller, relative uniform catchments

Thank you!!

Comparable landscape types





- Heathlands
- Lowland plain of Leipzig
- Mid-Saxony plate
- Mid-Saxony Hill country
- Hill country of Zwickau and Chemnitz
- Northern Erzebirge declivity
- Mountain ridge area

Surface response				
	CN2	SCS curve number, antecedent moisture condition II	-30%	+30%
	ESCO	Soil evaporation compensation factor	0.5	1
	SOL_AWC	Available soil water capacity	-30%	+30%
Subsurface response				
	GW_DELAY	Time required for water leaving the bottom of the root zone to reach the shallow aquifer	0	500
	GW_REVAP	Rate of transfer from shallow aquifer to root zone	0.02	0.2
	REVAPMN	Threshold water depth in shallow aquifer for percolation to deep aquifer to occur	0	500
	GWQMN	Threshold water depth in shallow aquifer for return to reach to occur	0	3000
	ALPHA_BF	Baseflow alpha factor, lower number means a slower response	0	0.9
	RCHRG_DP	Deep aquifer percolation fraction	0	1
Basin Response				
	SURLAG	Surface lag coefficient; controls fraction of water entering reach in one day	0.1	10
Channel Parameter				
	CH_K2	Effective hydraulic conductivity in main channel alluvium	0	100
	CH_N1	Manning’s “n” value for the tributary channels	0.01	0.3
	CH_N2	Manning's "n" value for the main channel	0.01	0.3
	MSK_CO2	Calibration coefficient used to control impact of the storage time constant for low flow	1	10
	MSK_X	weighting factor that controls the relative importance of inflow and outflow	0.01	0.4
Snow Parameter				
	TIMP	Snow pack temperature lag factor	0.01	1
	SFTMP	Snowfall temperature (ºC)	-1	3
	SMTMP	Snow melt base temperature (ºC)	-1	3
	SNOCOVMX	Minimum snow water content that corresponds to 100% snow cover (mm H2O)	0	500
	SMFMX	Maximum melt factor for snow	0	10
	SMFMN	Minimum melt factor for snow	0	10