Water-balance and runoff components in the Weser river basin simulated by WASIM-ETH - Validation by means of tritium balances

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Hydrologie und Geomatik für die Wasserwirtschaft

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with contributions

- Peter Hoffmann (diploma theses)
- Christian Gauger (diploma theses)
- Philipp Saile (work experience)
- Paul Königer (TRIBIL-support)
- Jörg Schulla (WASIM-ETH)

Report

Kern F.-J., Hoffmann P., Saile P. (2008): TRIBIL_2 – Tritiumbilanz deutscher Stromgebiete (Weser). Final Report Institut für Hydrology by order of Bundesanstalt für Gewässerkunde

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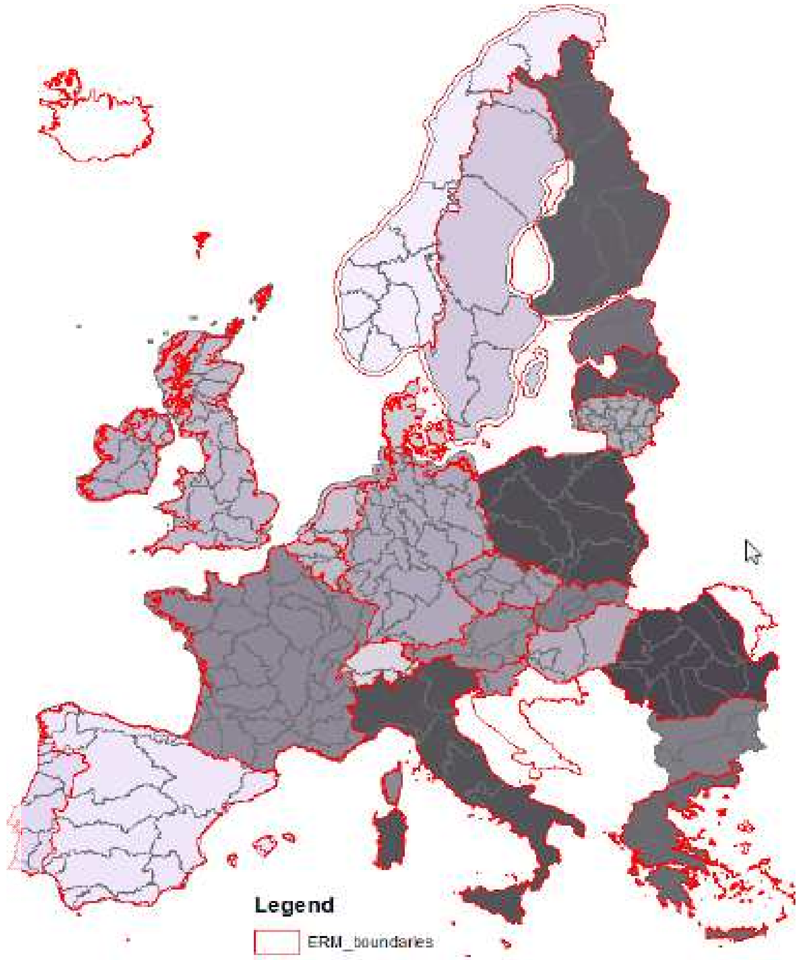
für die Wasserwirtschaft

1. Background of the work
2. Overview Weser river basin
3. View on selected parametrisation issues
4. DIFGA2000 & TRIBIL - contribution of mass transport to water balance models
5. Modelling results
6. Conclusion

Missions with regard to „water cycle“

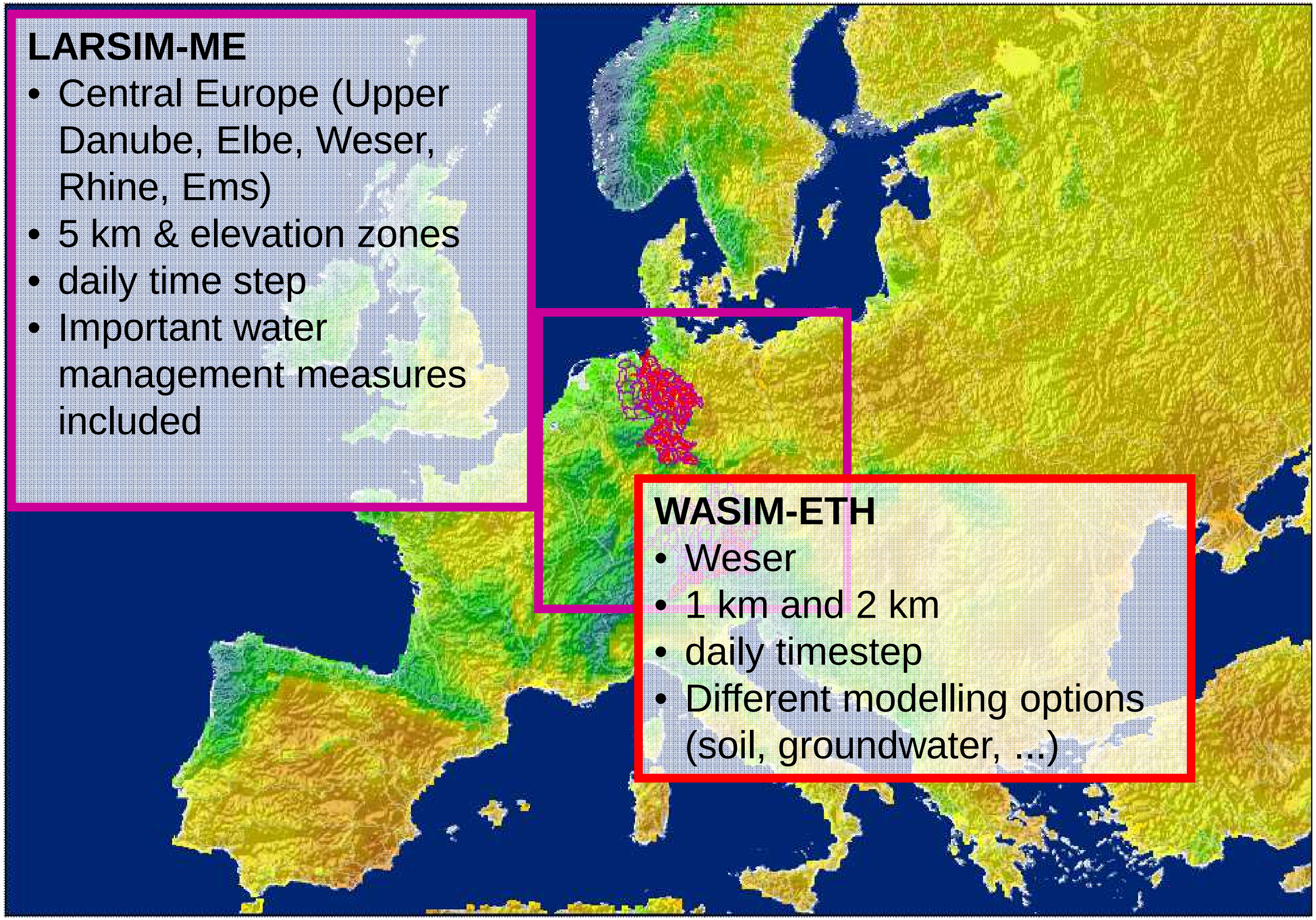
- Build up national and transnational hydrometeorological data bases
- Improve the understanding of hydrological processes and water balance modelling in large river basins
  (case study basins – macro scale basins)
- Build up hydrological monitoring and prediction systems by supporting the WMO initiative of “seamless prediction”



RBD subunit boundaries and ERM boundaries

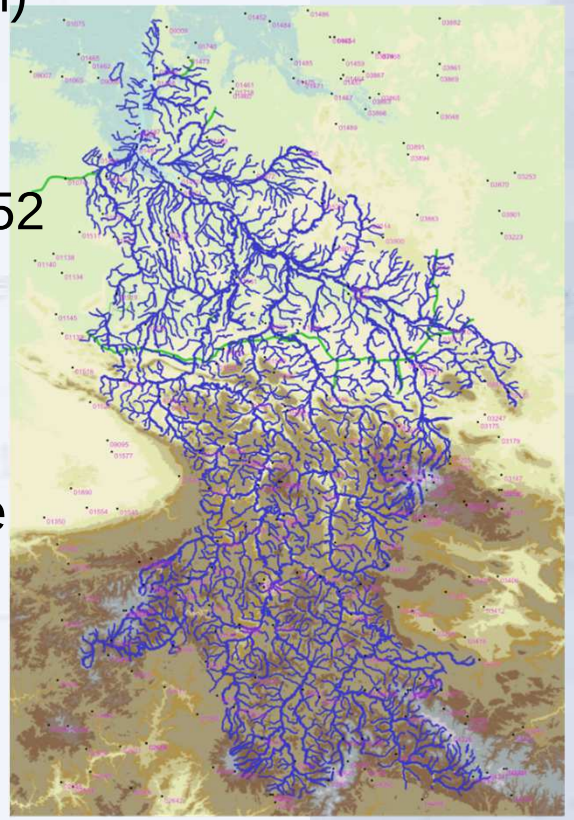
Source: EEA

Case study „River Weser basin“



Weser river basin

- area 46000 km^2 (lmax= 400 km, bmax=200 km)
- grid with 2 and 1 km^2 respectively
- daily timesteps for the hydrological years of 1952 to 2005
- differentiation into low mountain range in the south, lowlands and tide influences towards the coast of North Sea



Soil parametrisation using unsat-zone concept

BÜK1000 soil information of BGR

- detailed map in the scale 1:1 mio
- land use differentiated soil profiles (forest and arable land)
- horizon differentiated soil properties
- vanGenuchten soil water parameters according to HYPRES
- addition of ground water layers where appropriate

```
330323          {method= MultipleHorizons;
                #FCap = 28.17; mSB = 42.6; ksat_topmodel = 6.94E-7; suction = 426;

PMacroThresh    = 0.8;
MacroCapacity   = 13;
CapacityRedu    = 0.7;
MacroDepth      = 0.5;
horizon         = 1           2           3           4           5           6           7;
Name            = Ah          emGo        zemGr       zemGr       zemGr       zemGr       GW1;
ksat            = 0.00002000  0.00002430  0.00000578  0.00000578  0.00000578  0.00000578  0.00000578;
k_recession     = 0.92        0.9200      0.9200      0.9200      0.9200      0.9200      0.92;
theta_sat       = 0.45        0.4720      0.4140      0.4140      0.4140      0.4140      0.35;
theta_res       = 0.1         0.1000      0.1000      0.1000      0.1000      0.1000      0.1;
alpha           = 2.7         2.0000      2.3000      2.3000      2.3000      2.3000      2.3;
Par_n           = 1.17        1.1500      1.1000      1.1000      1.1000      1.1000      1.1;
Par_tau         = 0.5         0.5000      0.5000      0.5000      0.5000      0.5000      0.5;
thickness       = 0.1         0.4000      0.5000      0.5000      0.3000      0.2000      1;
layers          = 1           1           1           1           1           1           30;
}
```

Vegetation

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- CORINE (CLC2000)
- mapping on 12 land use classes
- monthly parametrisation (Albedo, rsc, rs_interception, rs_evaporation, LAI, z0, vcf, root depth, AltDep)

Gruppe	Bezeichnung	Zugeordnete CORINE-Einheiten
A1	Dicht bebaute Siedlungsflächen	1.1.1, 1.2.1, 1.2.2, 1.2.3
A2	Locker bebaute Siedlungsflächen	1.1.2, 1.2.4, 1.4.1, 1.4.2
B1	Ackerland	2.1.1
B2	Grünland	2.3.1, 3.2.1
B3	Dauerkulturen, Wein- und Obstbau	2.2.1, 2.2.2
B4	Verschiedene heterogene landw. Flächen	2.4.2, 2.4.3, 3.2.2, 3.2.4
C1	Laubwälder	3.1.1
C2	Nadelwälder	3.1.2
C3	Mischwälder	3.1.3
C4	Flächen ohne bzw. nur geringer Vegetation	1.3.1, 1.3.2, 1.3.3, 3.3.1, 3.3.2, 3.3.3
D1	Feuchtflächen, Torfmoore	4.1.1, 4.1.2, 4.2.1, 4.2.3
D2	Offene Wasserflächen, Gewässerläufe	5.1.1, 5.1.2, 5.2.1, 5.2.2

build up areas

arable land
grassland
permanent plantations

forests

open spaces with little or no vegetation
wetlands
water bodies

Hydrometeorology

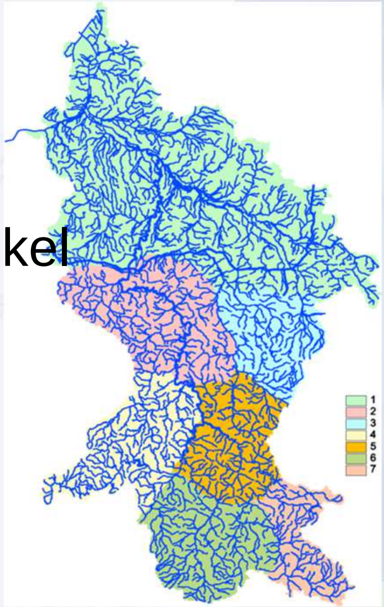
- Precipitation depth as daily grid of REGNIE rainfall data with monthly correction with a mean of +8%/y

station data

- temperature
- relative sunshine duration

regional altitude dependent regionalisation

- wind speed based on wind force station data (Häckel 1993)
- relative humidity

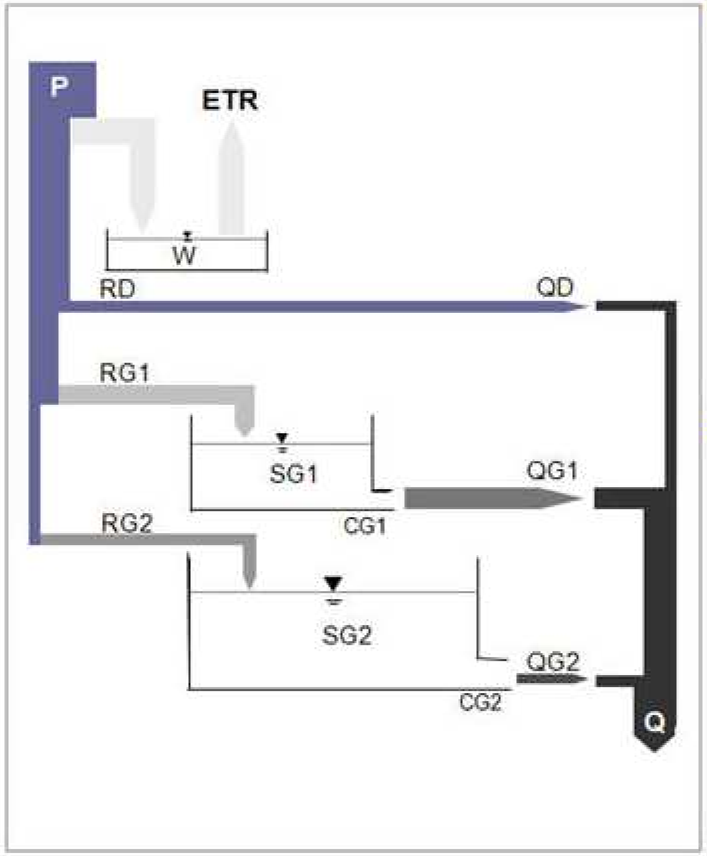


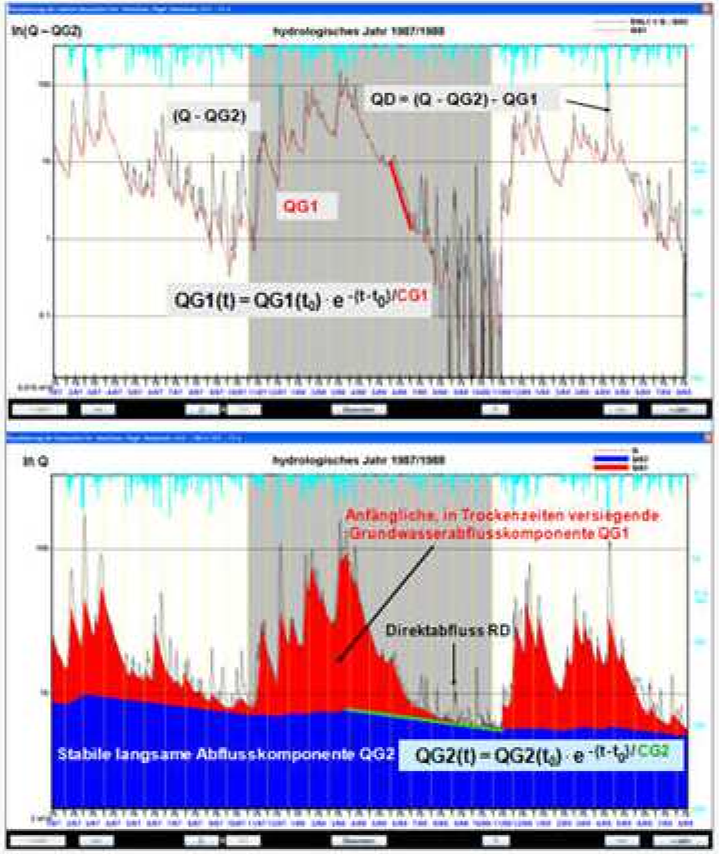
Model Calibration

Model performance tested according to

- visual comparison of hydrographs
- (log) coefficient of determination (d/m)
- (log) model efficiency (Nash Sutcliffe) (d/m)
- water balance
- volume error
- plausibility of water balance components
- runoff components (DIFGA2000)
- (mass transport Tritium)

Accompanying modelling – DIFGA2000



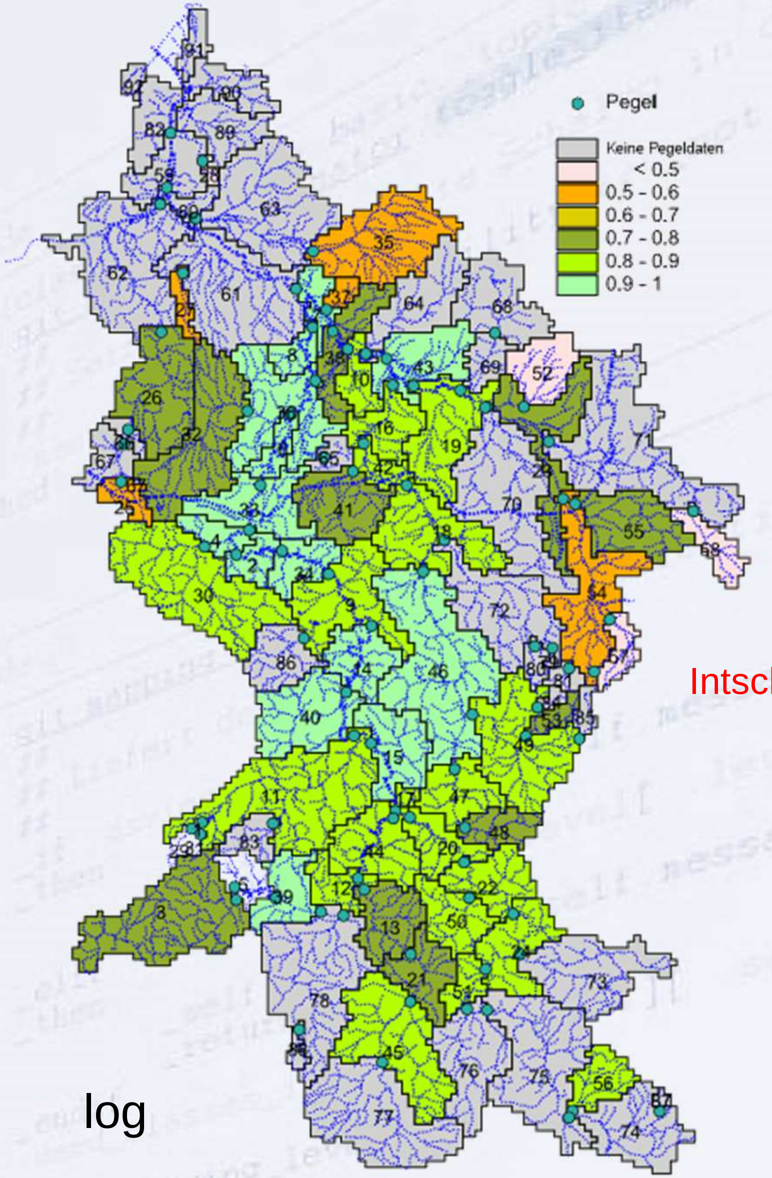


Schwarze R., Beudert B.(2009)

Simulation results

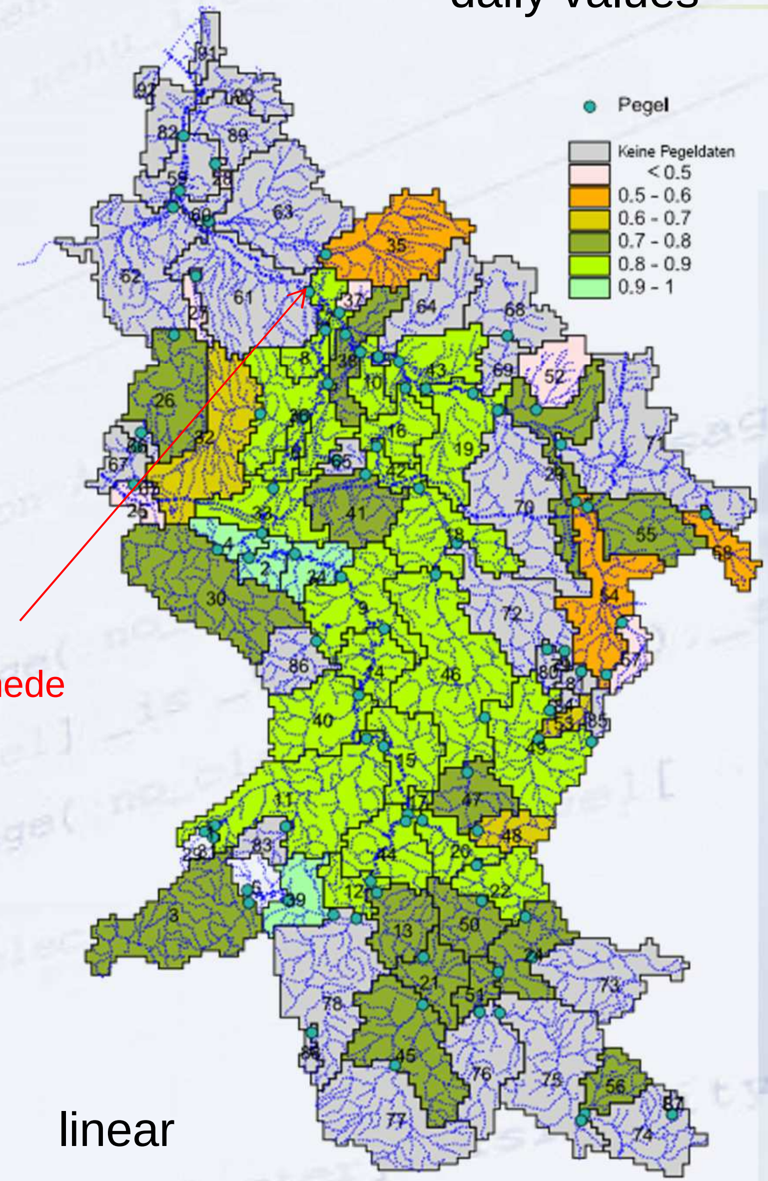
Nash Sutcliffe Efficiency

daily values



log

Intschede



linear

Simulation results

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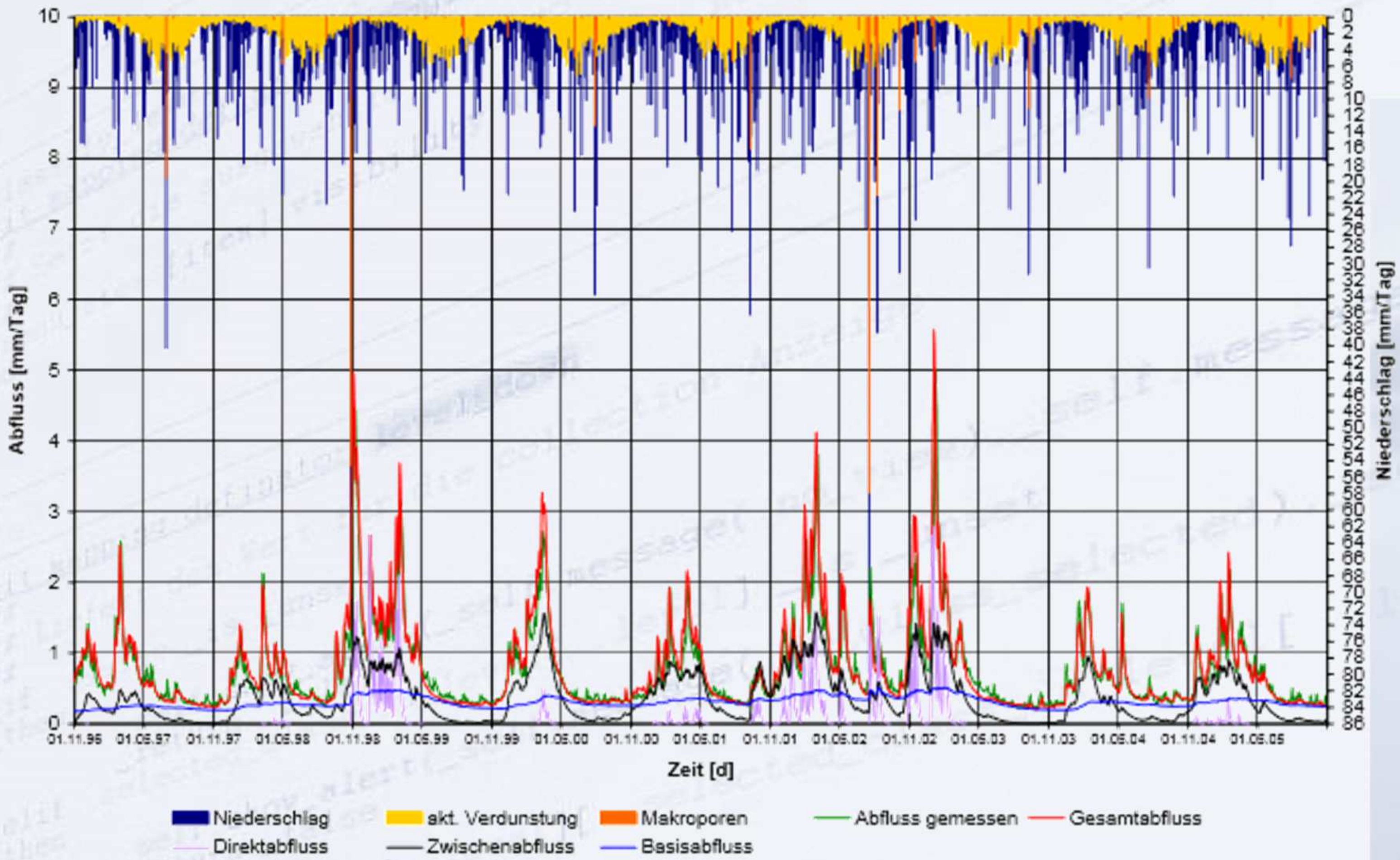

gauging station Intschede, daily values 1996-2005 (validation time per.)

Simulation results

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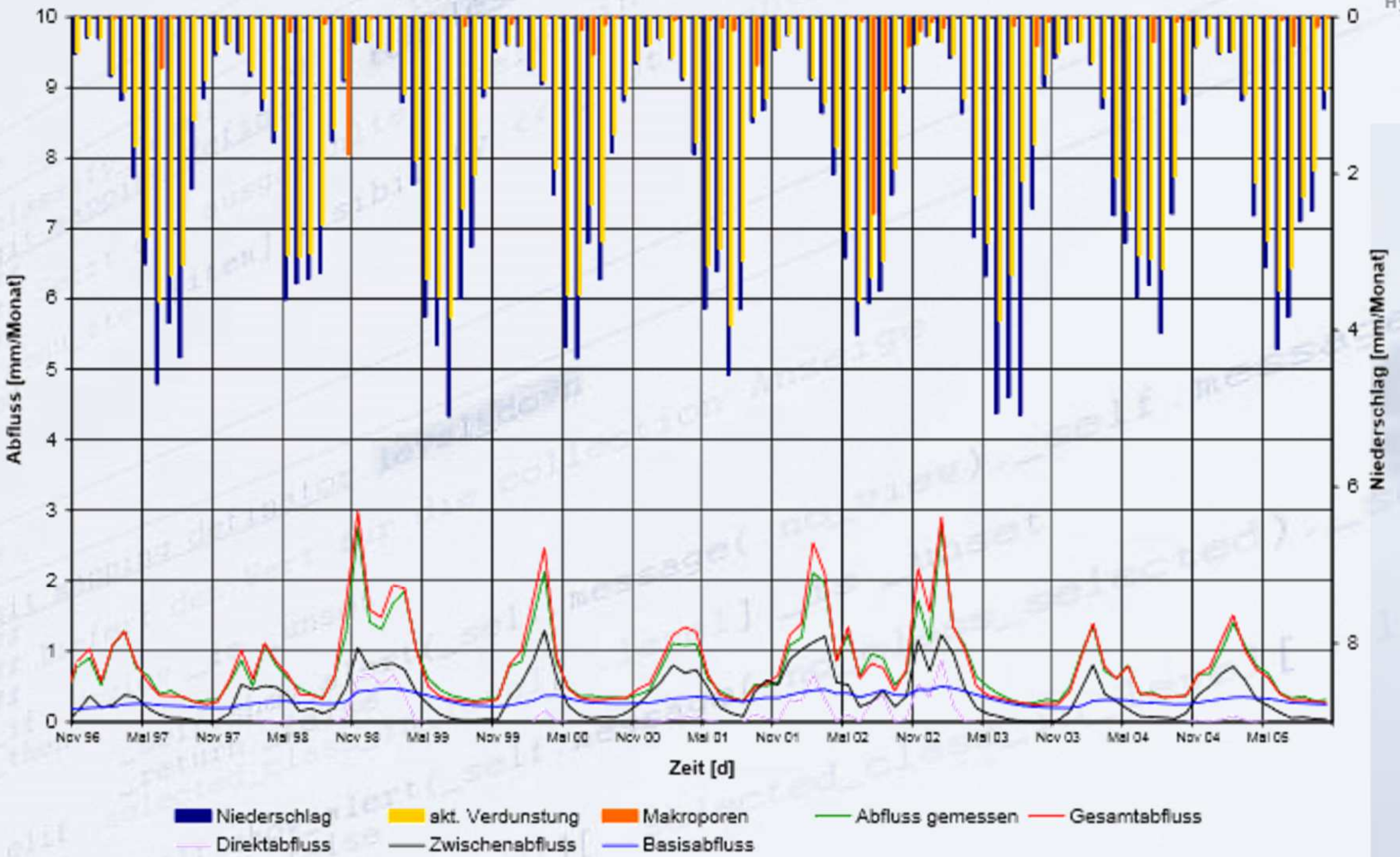
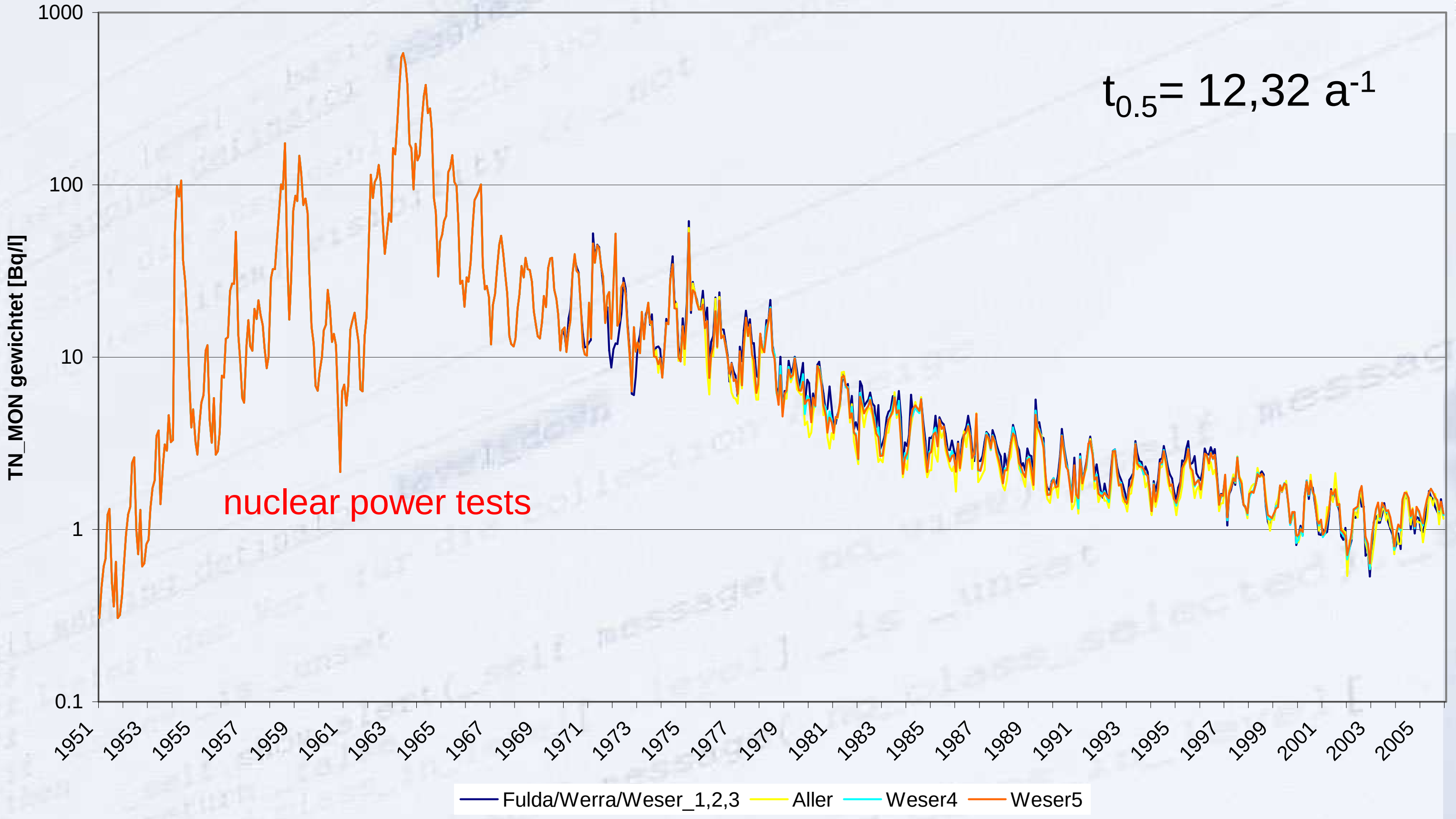


gauging station Intschede, monthly values 1996-2005 (validation time per.)

Contribution of mass transport to water balance models



- mass transport in WASIM without calibration
- independent model validation (storages)

WASIM – substance transport with Tritium

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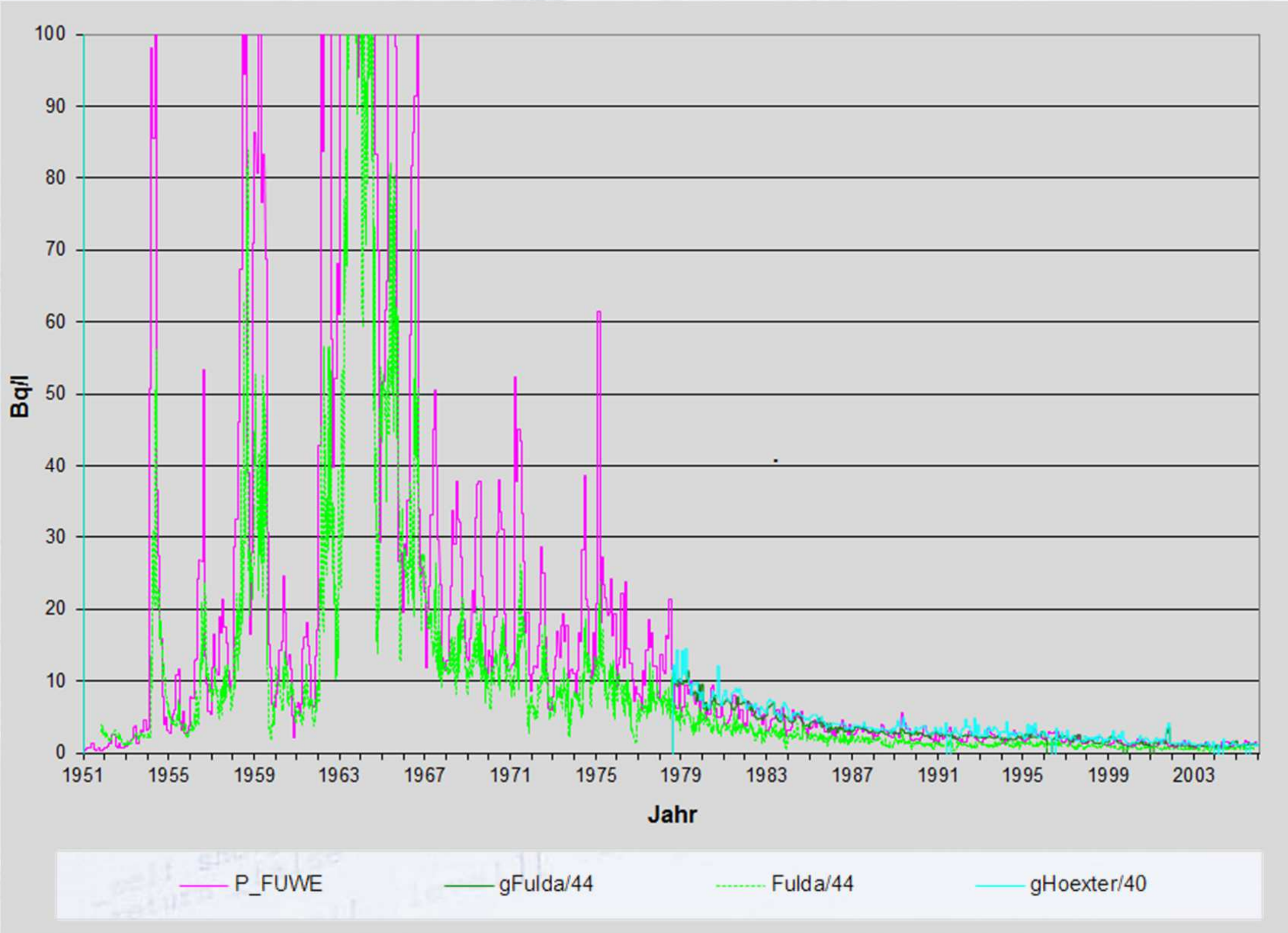
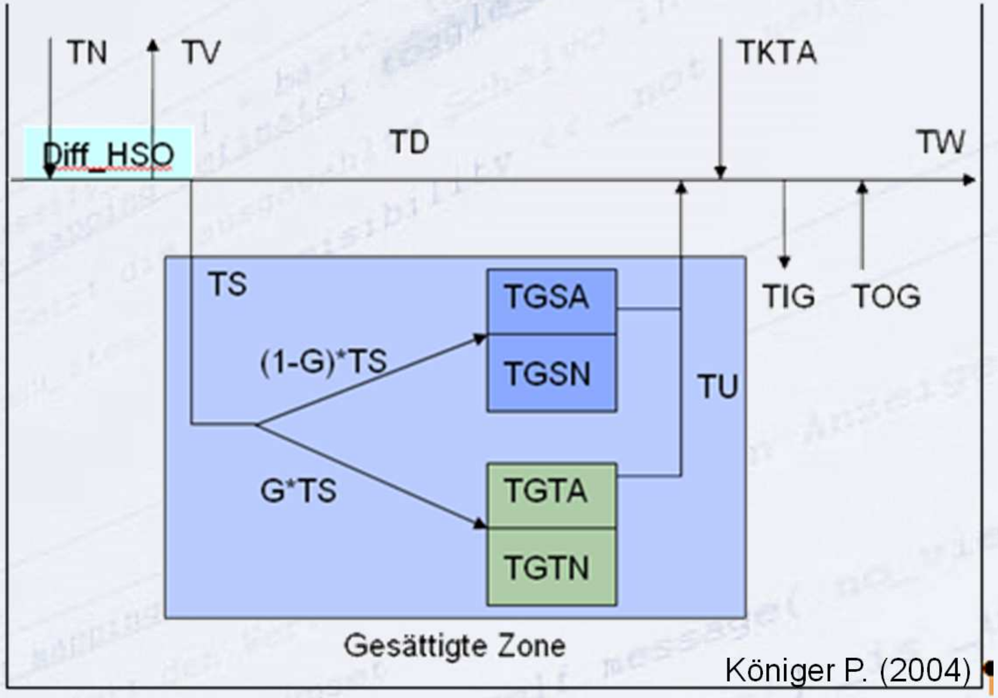
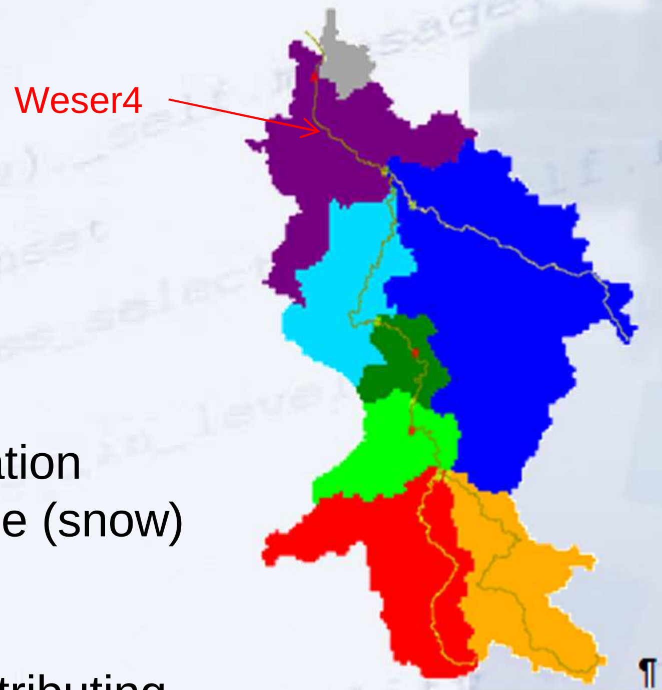


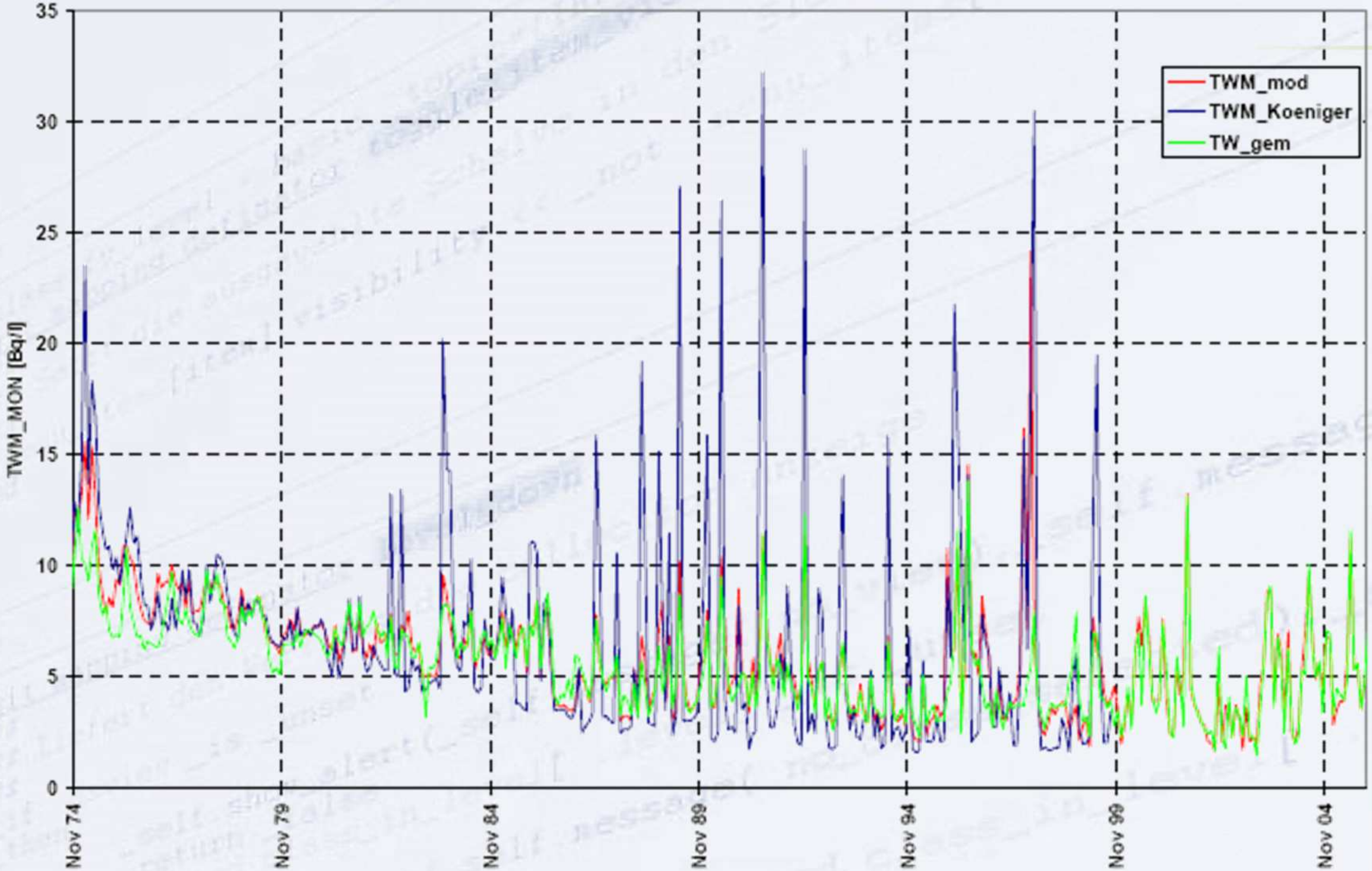
Accompanying modelling – TRIBIL





T = Tritium in storages in [Bq/l]
N = precipitation, V = transpiration, S = Percolation
Diff_HSO = change in surface soil water storage (snow)
G = percentage of base flow
GS + GT = fast and slow groundwater storage
A = active, runoff generating; N= not runoff contributing

Model results



catchment Weser4 , time series 1974 – 2005

including influence of nuclear power plants

Model results

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Gütemaß [-]	FULDA	WERRA	WESER1	WESER2	WESER3	ALLER	WESER4	WESER5
R^2	0,89	0,88	0,89	0,85	0,87	0,87	0,77	0,77
	0,78	0,77	0,77	0,72	0,76	0,77	0,73	0,73
E	0,89	0,88	0,89	0,84	0,85	0,81	0,7	0,59
	-2,31	-2,96	0,77	-2,12	-0,58	-4,71	-0,76	-0,94

	FULDA	WERRA	WESER1	WESER2	WESER3	ALLER	WESER4	WESER5	Rheine	Geeste	Emden
HMQ [mm]	283,78	350,57	305,73	314,1	275,34	229,59	269,18	268,3	307	295,00	286
Tau GW [a]	10,14	6,40	7,27	7,21	9,01	11,15	8,92	11,79	11,8	10,20	12,6
Tau ^{3}H [a]	6,48	4,71	5,17	5,14	5,99	6,87	5,95	7,11	7,11	6,50	7,39
Tau GW	40,60	62,10	44,50	43,30	91,10	92,00	92,20	92,50	11,8	10,20	12,6

time series 1963 – 2005 (WASIM/Königer (2004)

including influence of nuclear power plants

Time series analysis

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	Parameter	Kriterium	Fulda	Werra	Aller	Weser1	Weser2	Weser3	Weser4	Weser5	
temperature	T	Trend_Jahr	-	-	-	-	-	+ (M-K)	-	-	
		Trend_So	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	
		Trend_Wi	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	
		Sprung So	(PT)	(PT)	(PT)	(PT)	(PT)	(PT)	(PT)	(PT)	Sprung 1986 (Aller 1981)
		Sprung Wi	(PT)	(PT)	(PT)	(PT)	(PT)	(PT)	(PT)	(PT)	Sprung 1987
precipitation	N	Trend_Jahr	-	-	-	-	-	-	-	-	
		Trend_So	-	-	-	-	-	-	-	-	
		Trend_Wi	-	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	
		Sprung So	-	-	-	-	-	-	-	-	
		Sprung Wi	-	(PT)	-	(PT)	(PT)	(PT)	-	-	Sprung 1978/79
snow water equivalent	WEQ	Trend_Jahr	- (M-K)	- (M-K)	- (M-K)	- (M-K)	- (M-K)	- (M-K)	- (M-K)	- (M-K)	Sprung 1986 (Aller 1982)
		Sprung Wi	(PT)	(PT)	-	-	-	(PT)	(PT)	(PT)	Sprung 1971/1987
actual transpiration	Va	Trend_Jahr	-	-	-	-	-	-	-	-	
		Trend_So	-	+ (M-K)	+ (M-K)	-	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	div. Je Gebiet
		Trend_Wi	-	+ (M-K)	+ (M-K)	-	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	1986-1989
		Sprung So	-	(PT)	(PT)	-	(PT)	(PT)	(PT)	(PT)	Sprung 1980/1991
		Sprung Wi	-	(PT)	(PT)	-	(PT)	(PT)	(PT)	(PT)	Sprung 1980/1991
potential transpiration	Vpot	Trend_Jahr	-	-	-	-	-	+ (M-K)	-	-	
		Trend_So	-	-	+ (M-K)	-	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	Sprung 1986 (Aller 1982)
		Trend_Wi	-	+ (M-K)	+ (M-K)	-	+ (M-K)	+ (M-K)	+ (M-K)	+ (M-K)	Sprung um 1986
		Sprung So	-	-	(PT)	-	(PT)	(PT)	-	-	Sprung 1987 (1981)
		Sprung Wi	-	(PT)	(PT)	-	(PT)	(PT)	(PT)	(PT)	Sprung 1985-1988 (1980)
mean runoff simulated	MQ	Trend_Jahr	-	-	-	-	-	-	-	-	
		Trend_So	-	-	-	-	-	-	-	-	
		Trend_Wi	-	+ (M-K)	-	-	-	-	-	-	
		Sprung So	-	-	-	-	-	-	-	-	
		Sprung Wi	-	-	-	-	-	-	-	-	
mean runoff observed	Mqgem	Trend_Jahr		-	- (M-K)	-	- (M-K)	-	-	-	
		Trend_So	-	-	-	-	-	- (M-K)	-	-	
		Trend_Wi	-	-	-	-	-	-	-	-	
		Sprung So	(PT)	-	-	-	(PT)	-	-	-	Sprung 1987
		Sprung Wi	-	-	-	-	-	-	-	-	
base flow	Qbas	Trend_Jahr	-	-	-	-	-	-	-	-	
		Trend_So	-	-	-	-	+ (M-K)	-	-	-	
		Trend_Wi	-	- (M-K)	-	-	-	-	-	- (M-K)	
		Sprung So	-	-	-	-	-	-	-	-	
		Sprung Wi	-	-	-	-	-	-	-	-	

Conclusions

- model data for 1k und 2k prepared for 1952 - 2005
- model results for 1K and 2k model very similar
- some errors in WASIM-ETH were fixed with the support of J. Schulla
- diverse model concepts testet and several parameter sensitivity analysis conducted
- multifactorial calibration and good agreement with concepts using runoff segmentation and substance transport
- predominant good fit for the whole Weser basin
- trends detected according to expectations in climate change, e.g. increasing temperature and transpiration, increasing winter precipitation in most subcatchments, decreasing water equivalent of snow cover

Conclusions

- substance transport in WASIM-ETH suitable in principle - could be a valuable additional calibration or validation module
- coupled water-balance and mass-transport models together with isotope-tracer measurements can make a valuable contribution to the characterisation of subsurface water storage
- but substance transport of ^{3}H unsatisfactory at that time because of software shortcomings
- to model environmental isotope tracers like ^{3}H, ^{2}H or ^{18}O, some processes like isotope fractionation during evapo(transpiration) should be accounted for

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Thanks to the audience...

Special view on parametrisation issues

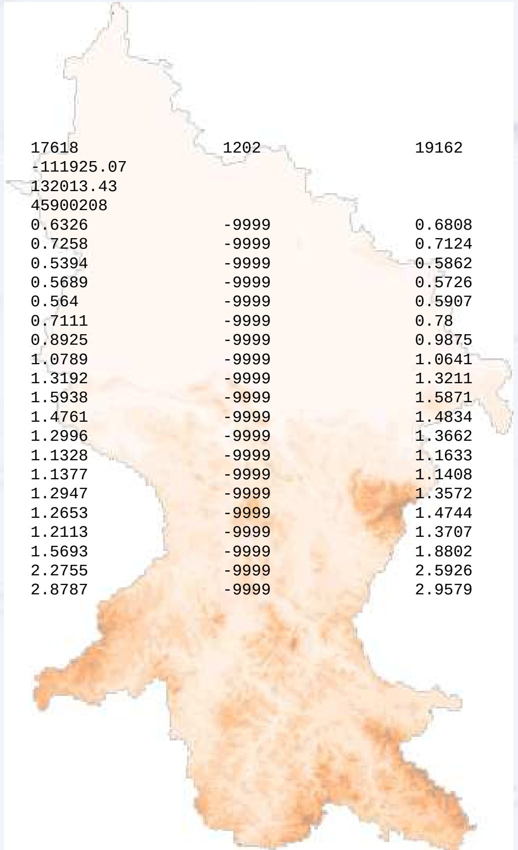
1. Parametrisation in general
2. Topography
3. Soil
4. Vegetation
5. Hydrometeorology

Parametrisation

- Control-File
- Areal data as Grids (ASCII/Binary)
- Time Series data as ASCII data series

Abflussspende (mm/d)

YY	MM	DD	HH	103	17618	1202	19162
YY	MM	DD	HH	-123045.81	-111925.07		
YY	MM	DD	HH	43880.46	132013.43		
YY	MM	DD	HH	44100206	45900208		
1951	1	1	24	0.9563	0.6326	-9999	0.6808
1951	1	2	24	0.9563	0.7258	-9999	0.7124
1951	1	3	24	0.9563	0.5394	-9999	0.5862
1951	1	4	24	0.9563	0.5689	-9999	0.5726
1951	1	5	24	0.9563	0.564	-9999	0.5907
1951	1	6	24	0.9563	0.7111	-9999	0.78
1951	1	7	24	0.9563	0.8925	-9999	0.9875
1951	1	8	24	0.9563	1.0789	-9999	1.0641
1951	1	9	24	0.9563	1.3192	-9999	1.3211
1951	1	10	24	1.1324	1.5938	-9999	1.5871
1951	1	11	24	1.015	1.4761	-9999	1.4834
1951	1	12	24	0.8976	1.2996	-9999	1.3662
1951	1	13	24	0.9563	1.1328	-9999	1.1633
1951	1	14	24	0.9563	1.1377	-9999	1.1408
1951	1	15	24	0.8976	1.2947	-9999	1.3572
1951	1	16	24	0.9563	1.2653	-9999	1.4744
1951	1	17	24	0.8976	1.2113	-9999	1.3707
1951	1	18	24	1.9293	1.5693	-9999	1.8802
1951	1	19	24	2.7682	2.2755	-9999	2.5926
1951	1	20	24	3.5147	2.8787	-9999	2.9579



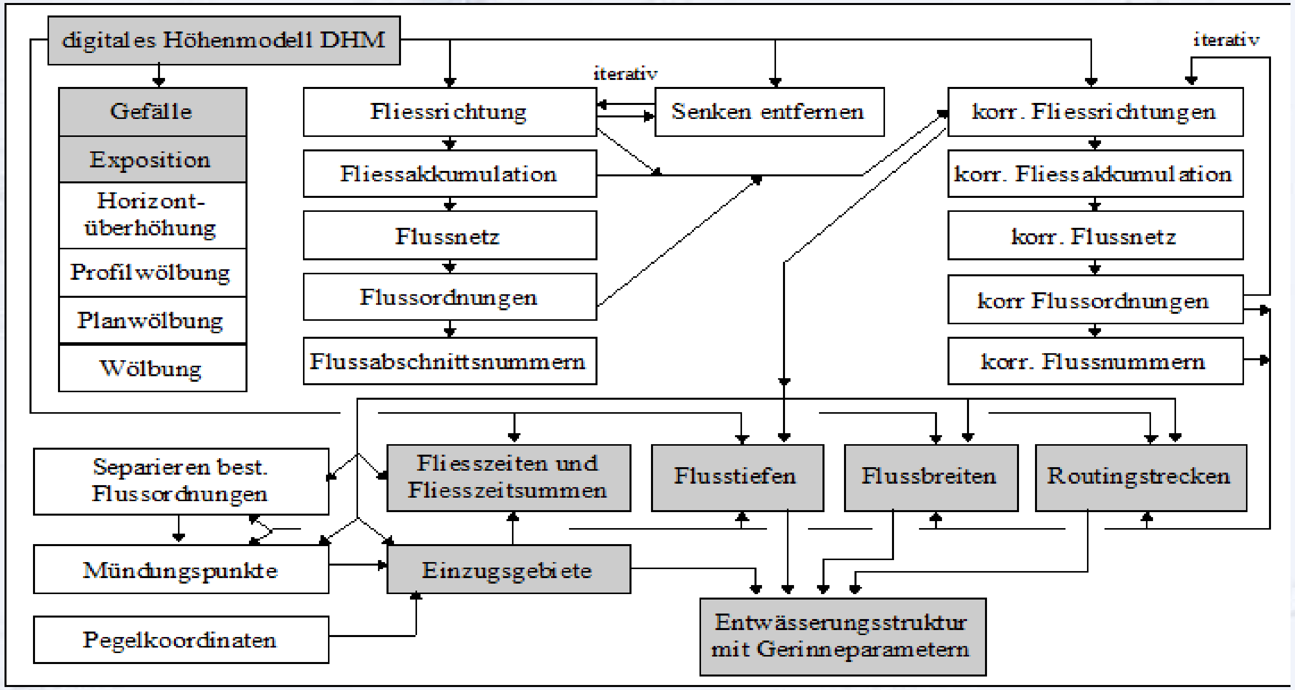
Topography

Diverse datasets

- DGM1000 des BKG
- 30“-DEM USGS (as 500 or 1000 m-DEM also base data in HAD)
- SRTM (Shuttle Radar Topography Mission)

Aggregation into 1k and 2k grids respectively

TANALYS



Simulation results

Nash-Sutcliffe Efficiency

monthly values

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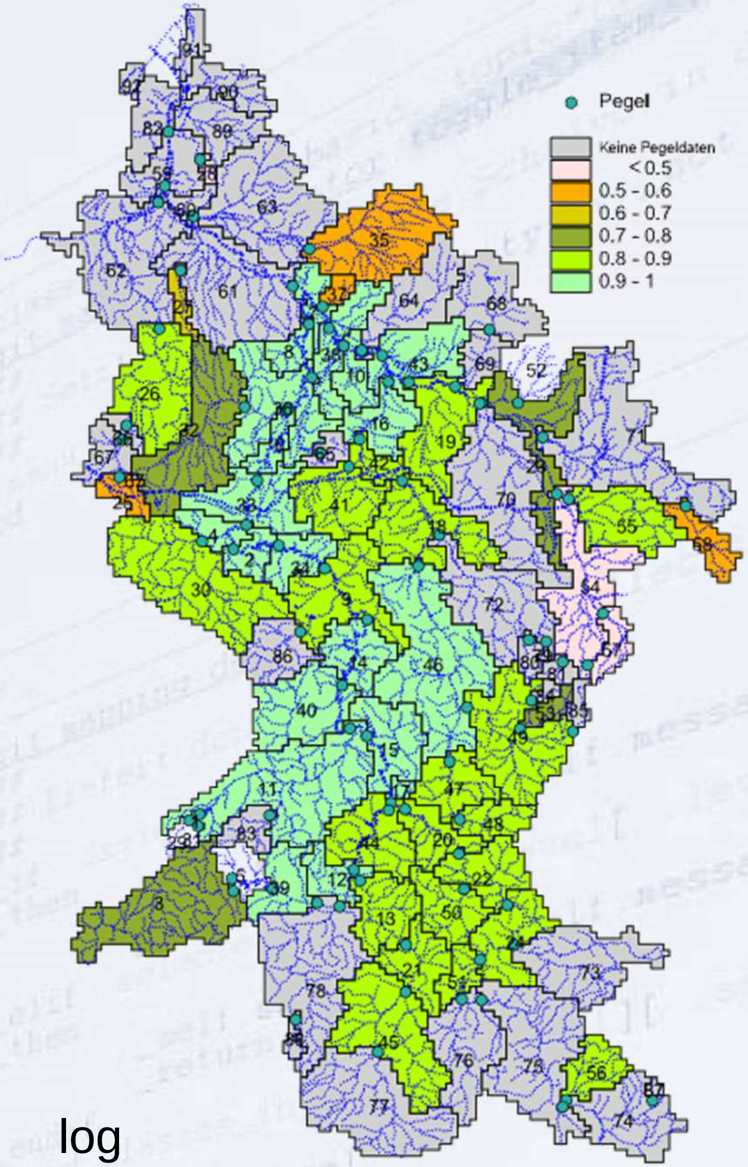
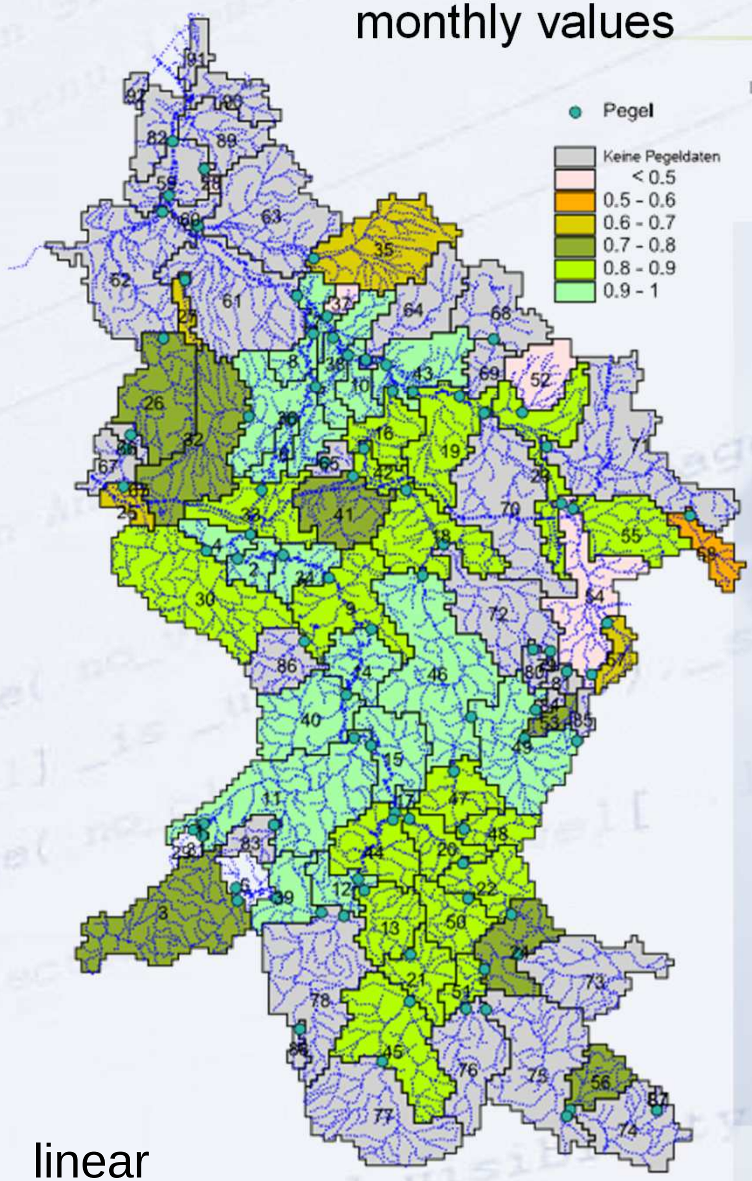
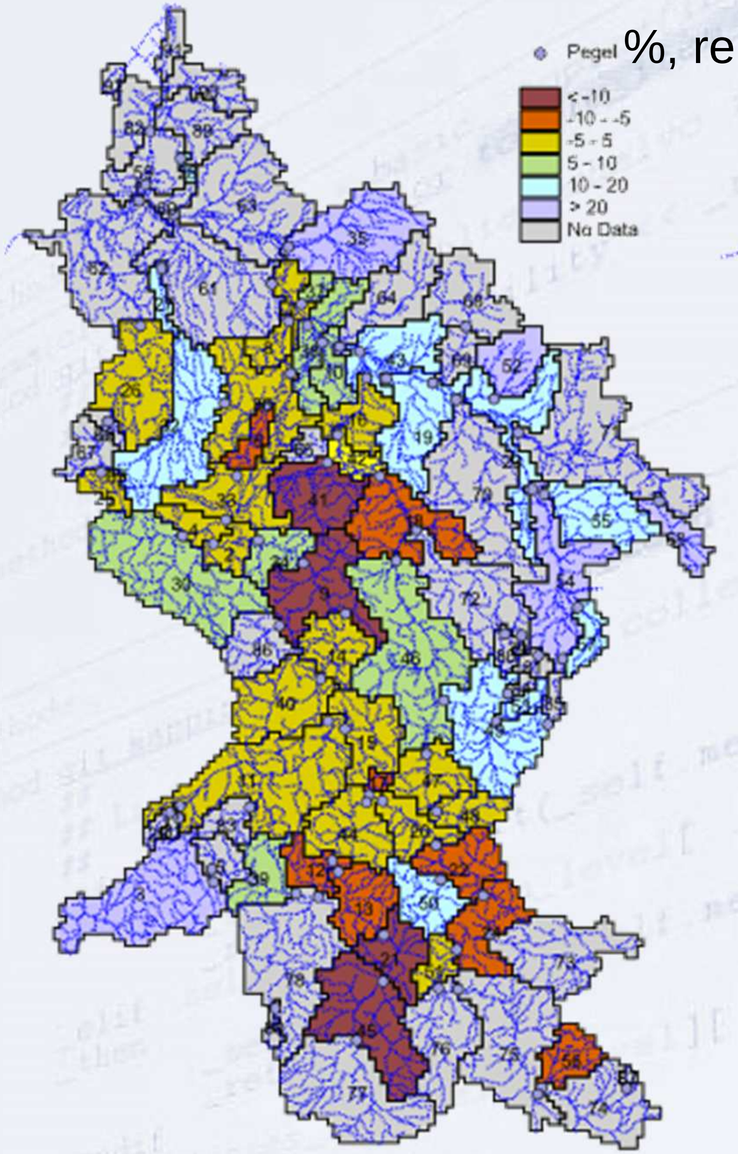


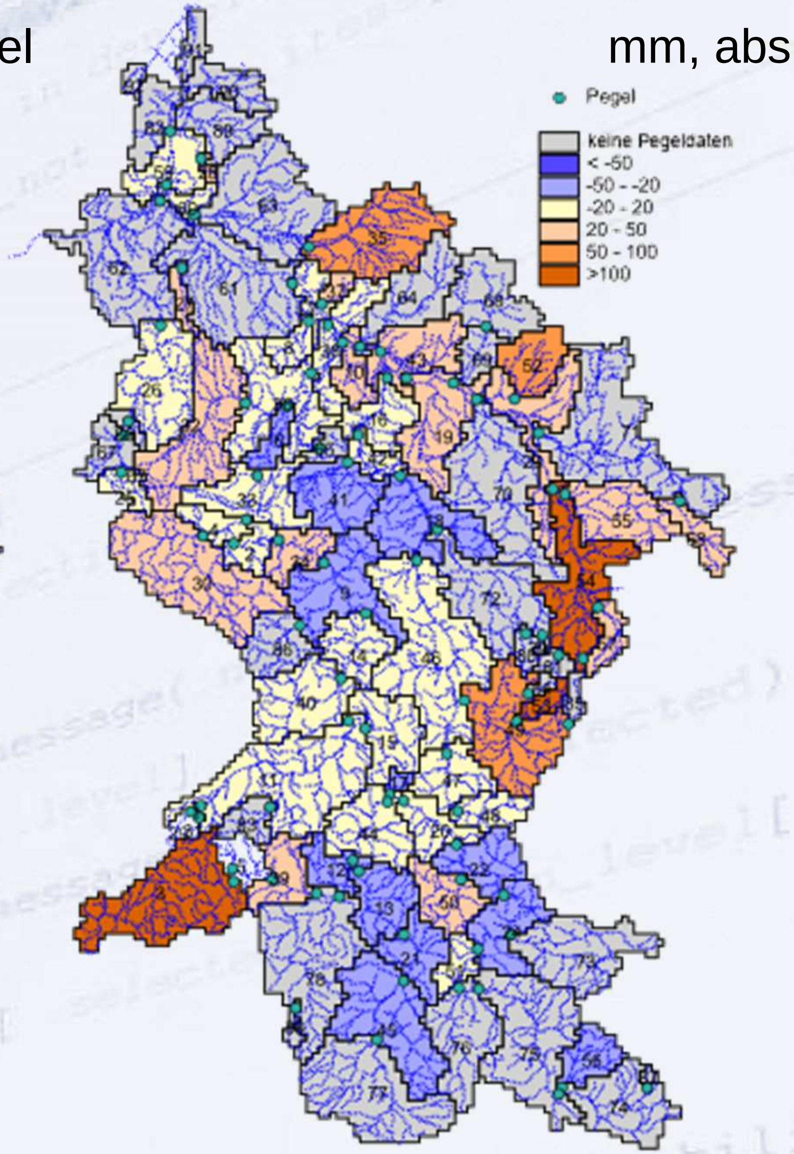
log



linear

deviation of run-off Qsim / Qobs





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Sources of model misfit

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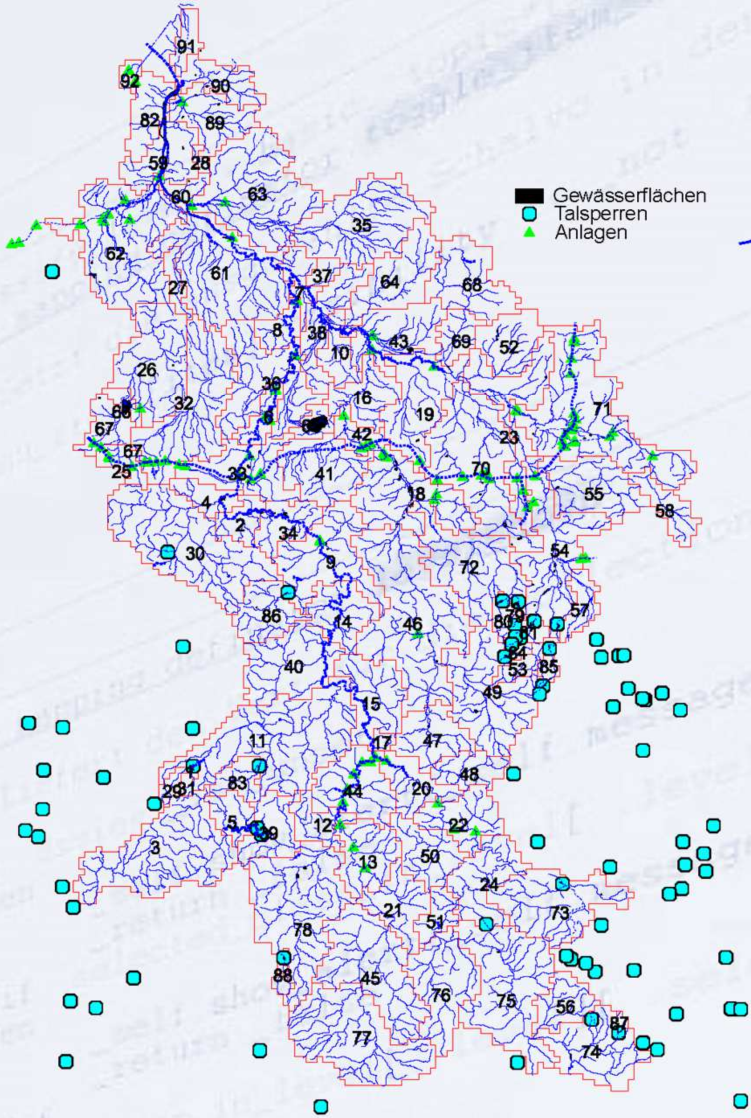
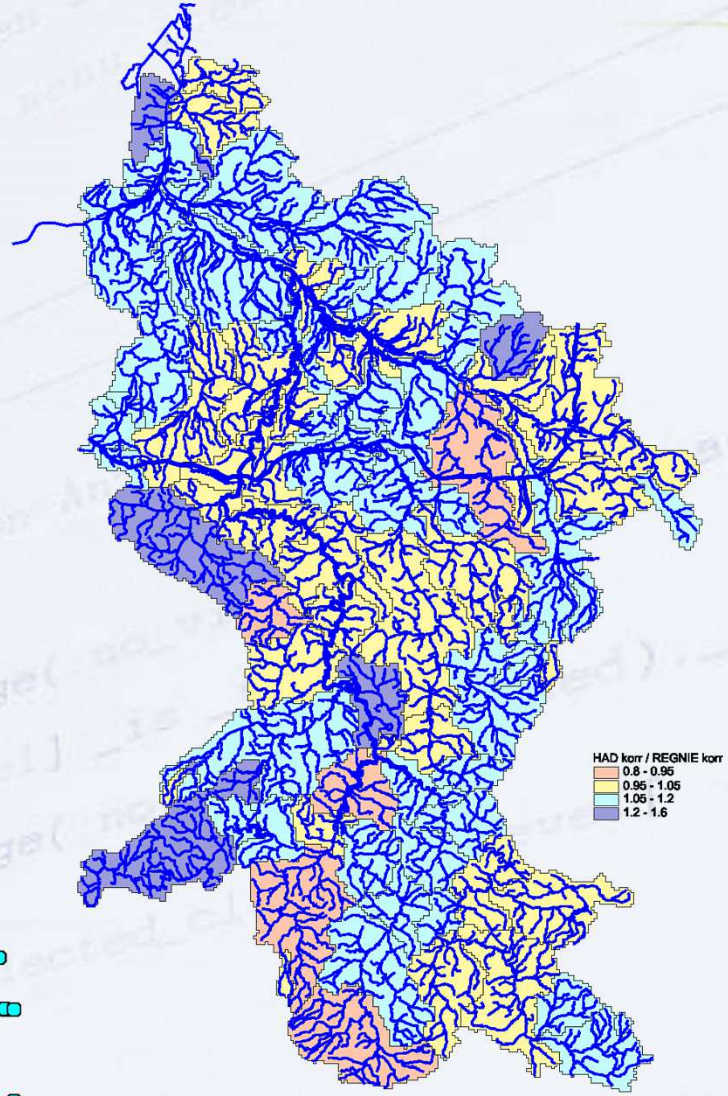


major water management structures



precipitation
HAD corr/ REGNIE corr

Time series analysis (homogenity)

Trend (Mann-Kendall)

- nonparametric Test
- no assumption on normal distribution
- no assumption on the sort of trend
- significance level 95%

Significant trends for Temperature, Precipitation, actual and potential transpiration in many subcatchments

jump test (Pettitt)

- nonparametric Test
- significance level 95%

Significant jumps around 1987 in several catchments for different parameters