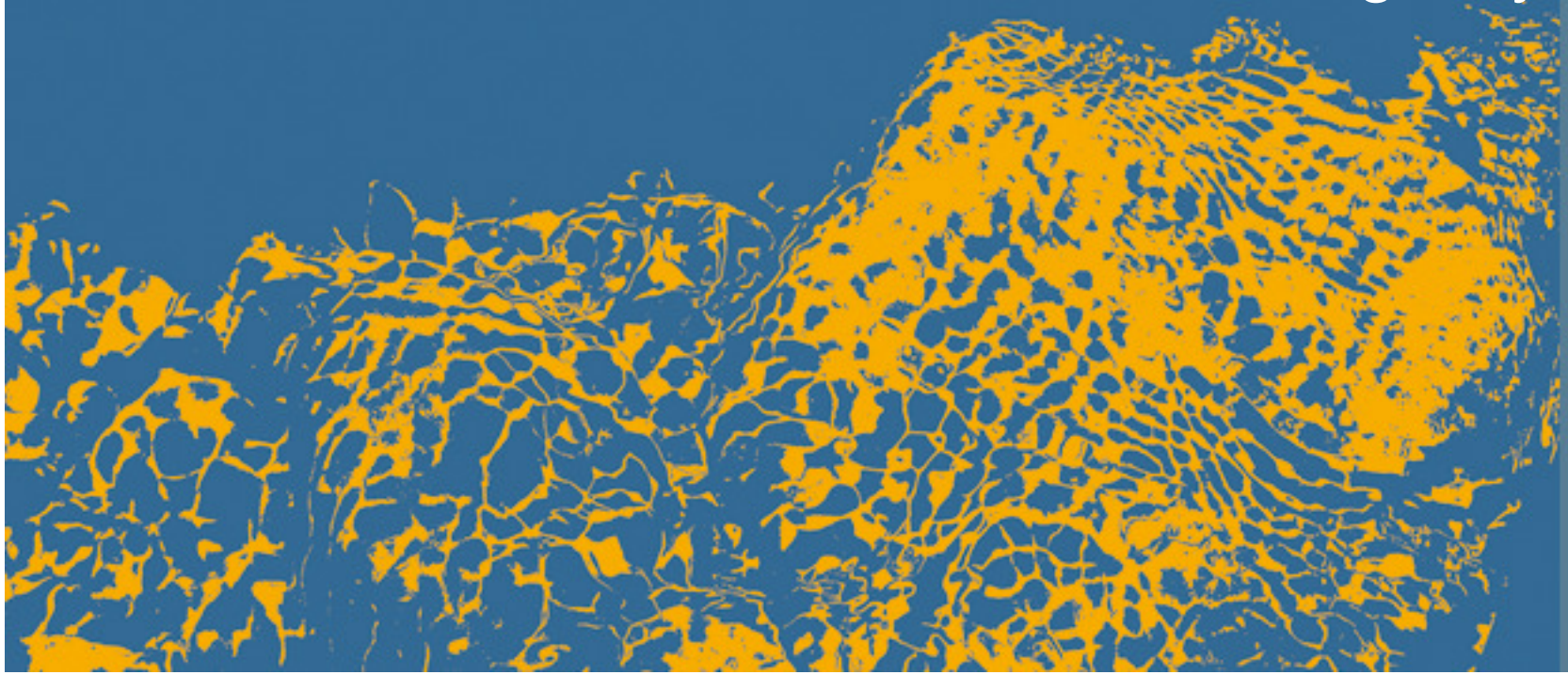
Bavarian Environment Agency

Areal hydrological modelling of Bavaria within the cooperation project KLIWA

Holger Komischke for Unit 81

Bavarian Environment Agency



Introduction

- climate change already had impacts on the water regime

flood at river Inn flowing into Danube (city of Passau) (August 2002)
photo: Bavarian State Ministry of the Environment and Public Health

low flow at Isar river flowing into Danube (August 2003)
photo: www.agroluftbild.de

- **Key questions** for the Bavarian Environmental Agency (LfU), institution of the Bavarian Water Management Administration:

  – What is state of knowledge about regional climate change and its impacts ?
  – What are the consequences of climate change for water management?
  – How secure are the different findings?
  – Which operational strategies have to be developed for water management ?

Introduction

- In search of answers: research programs at the LfU

  – The cooperation project KLIWA (www.kliwa.de):
  since 1999 with partners in Southern Germany:
  Baden-Württemberg, Rheinland-Pfalz, Bavaria and the German Meteorological Service

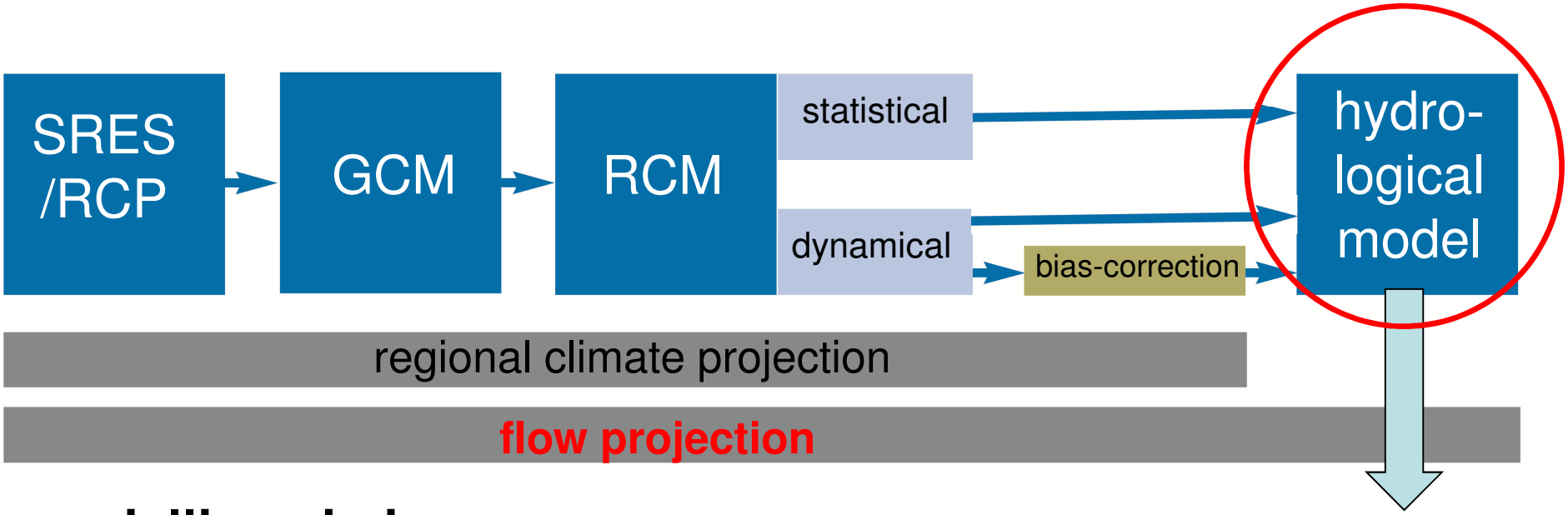
  “Climate Change and Consequences for water management"

  – The EU Interreg IVb project AdaptAlp (www.adaptalp.org):
  2008 – 2011

  "Adaptation to Climate Change in the Alpine Space"

How do we get there?

For analysis of future changes in hydrology → regional climate projections coupled with hydrological modelling

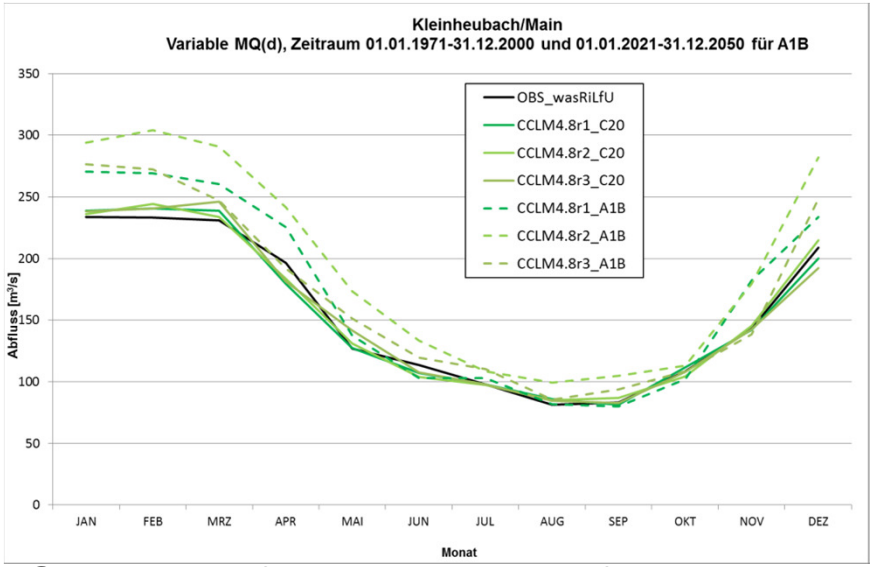


modelling chain

results / communication

Hydrological modelling for Bavaria WaSiM-ETH

- Our aims in hydrological modelling:
  - water balance
  - flow at gauges
  - low/high flow indicators
  - extremes? (can we model these)
  - groundwater – not really!



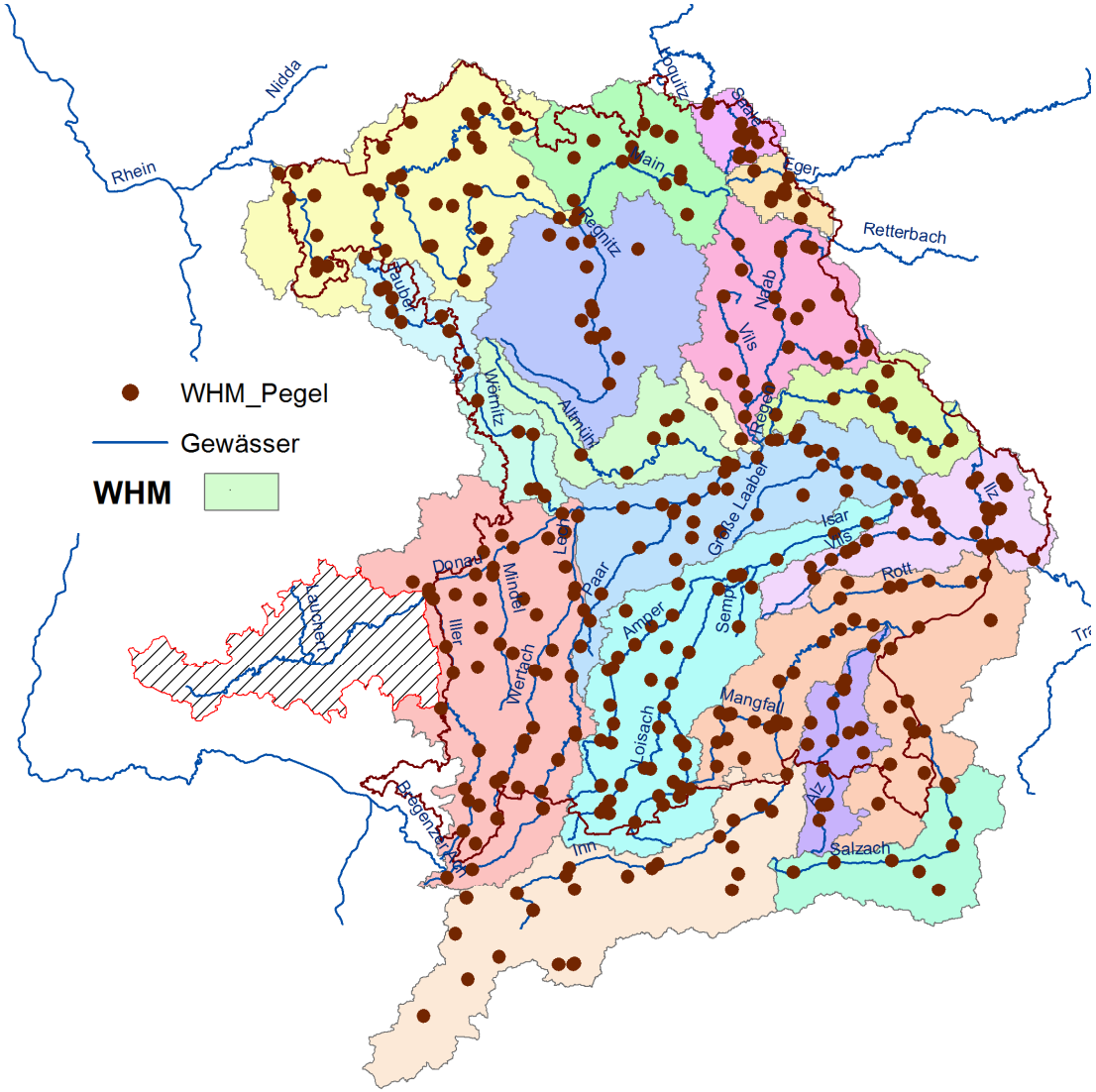
Changes of monthly mean flow at Kleinheubach/Main

⇒ modelling for at least 30 years → results 30 year means

⇒ extract robust changes for water balance (mean, high & low flows)

⇒ regional differences and challenges?

Modelling with WaSiM-ETH (about 90.000 km²)



19 models

more than 400 gauges

daily on a raster of 1x1 km

WaSiM-variants:

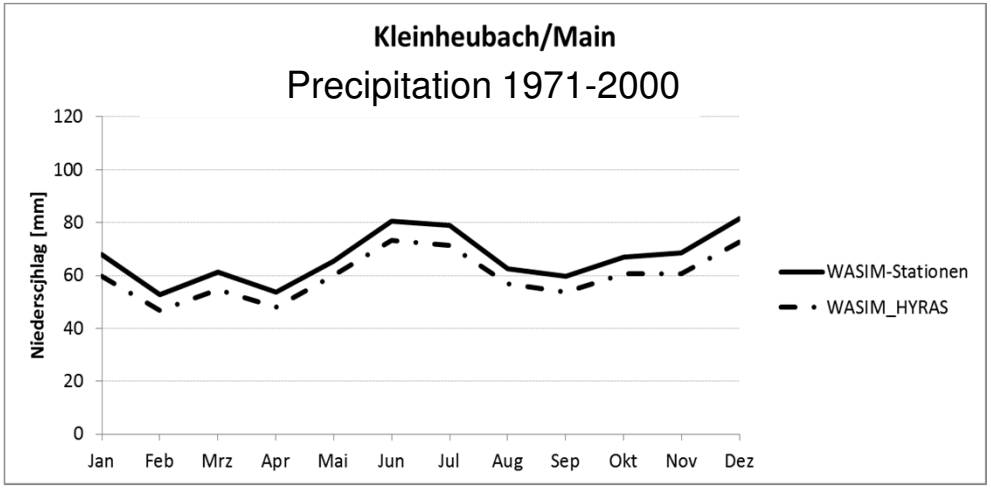
→ TOPMODEL (since 2001)

→ currently update to Richards 9.1.0;

Assembling / update of hydrological models:

Assembling:

- measured meteo-data
- available areal data (land use…)
- model version
- homogenous parameterisation
- use of reservoirs and water transfer?



Update:

- new versions with bug fixes or better methods
- new questions or requirements
- better or other data

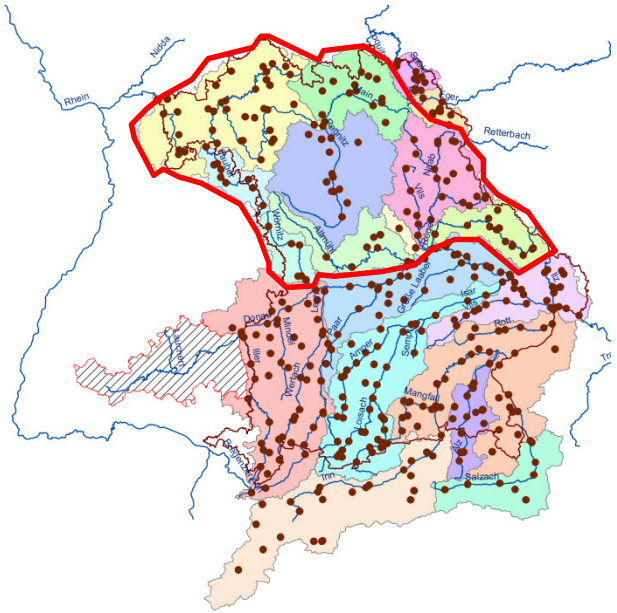
History of the hydrological modelling at the LfU

- First WaSiM-Models in 2001

  TOPMODEL, meteorological stations with corrected precipitation, one model at a time (most work is commissioned); manual calibration

⇨ Nearly all river catchments north of Danube modelled until 2006

⇨ Different parameterizations per model and one model at a time solution lead to jumps in the results at model boundaries

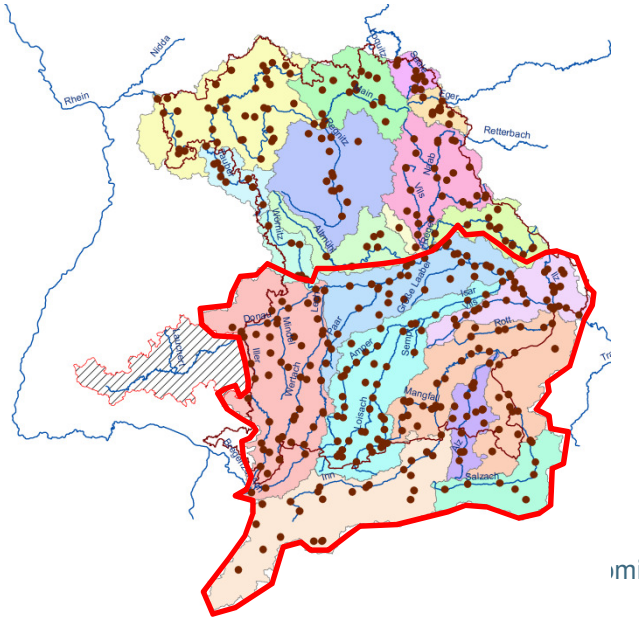


History of the hydrological modelling at the LfU

- With Southern Danube tributaries switch to Richards-Version in 2009; assembling and calibration of all 7 models at once!; manual calibration

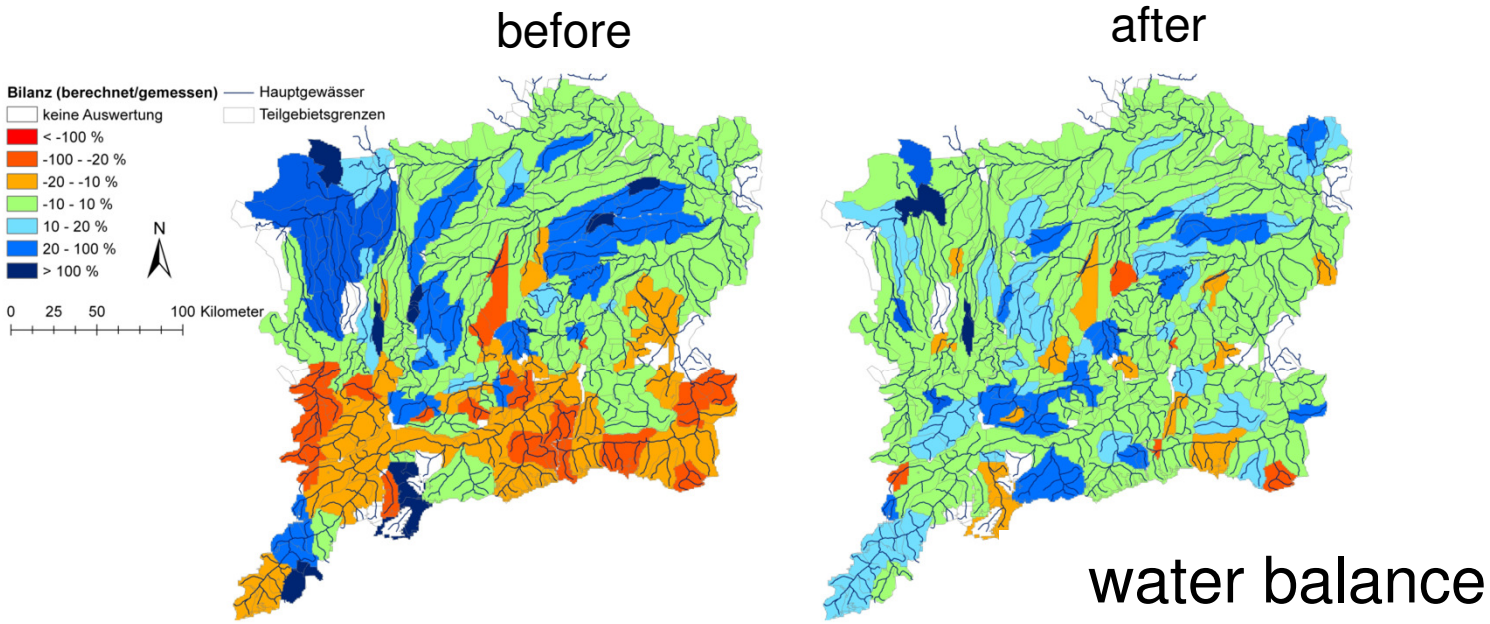
⇨ Some challenges in the Alpine area and the Alpine foreland

- Interpolation of precipitation ⇨ module regional superposition
- Intensive water management and many lakes ⇨ incorporation of lakes and inflow/outflows in WaSiM



Interpolation of meteorology

Development of the module Regional Superposition for interpolation; here used for precipitation



⇒ different zones of interpolation with different combinations

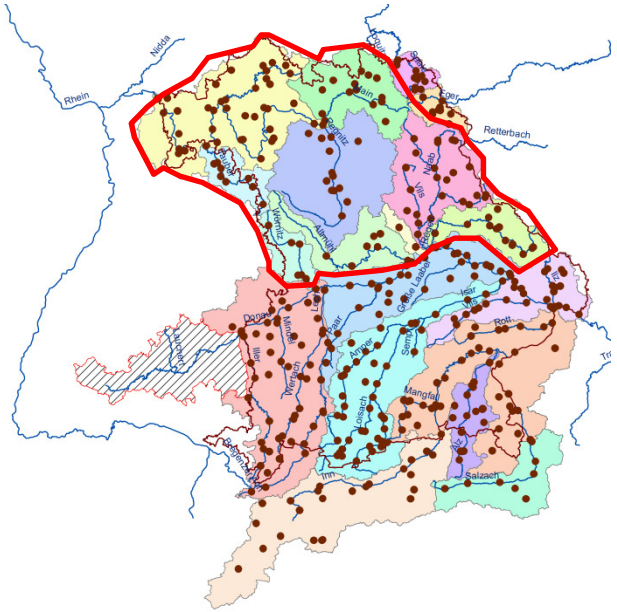
AdaptAlp(Pöhler et al., 2010)

History of the hydrological modelling at the LfU

- Update of all older TOPMODEL-Models to Richards and first modelling for Danube river until 2014; automated calibration

⇨ Update necessary:

- new version with bug fixes or better methods
- Richards instead of TOPMODEL
- update of all models at once,
  → same, more homogenous parameterization for all
- new references for meteorological input (DWD-HYRAS 1x1 km)



⇨**Now all models in a present Richards-Version**

Calibration and used criteria

Calibration of the hydrological models

- in the past:

  manual to whole flow continuum (mean flow, low flows, high flows)

- present calibration (Willems & Stricker 2013, i.A. LfU):

  automated calibration with SCE-UA

  – multithread: parallel optimisation in different catchments

  – multi criteria: NSC(lin/log) for overall flow and components (baseflow); plausible bandwidth of ETR

Tab. 9: Im Rahmen der Kalibrierung betrachtete Modellparameter und ihre Sensitivitäten

Parameter	Einheit	Modellsensitivität (qualitativ)
Skalierung für Basisabfluss	[mm/h]	sehr hoch
Speicherkonstante für Basisabfluss	[m]	sehr hoch
Speicherkonstante Direktabfluss	[h]	mittel
Speicherkonstante Interflow	[h]	mittel
Entwässerungsdichte	[-]	mittel
Anteil Direktabfluss aus der Schneeschmelze	[-]	gering
Abnahmekonstante	[-]	hoch
gesättigte hydraulischen Leitfähigkeit	[m/s]	meist gering
Van-Genuchten Parameter	m^{-1}	sehr hoch
Van-Genuchten Parameter	[-]	mittel
Van-Genuchten Parameter	[-]	sehr hoch

What criteria do we use for modelling:

⇨What kind of criteria shall you use?

⇨Which quality are reachable / what do we need for later use?

- water balance, NSC, KGF, water soil content, plausibility of the indicators
- correct reproduction of measured trends in the past
- computing time of model (most time, the demands were to high in the beginning)
- quality of input data, especially meteorology (e.g. correction of precipitation or method of interpolation)

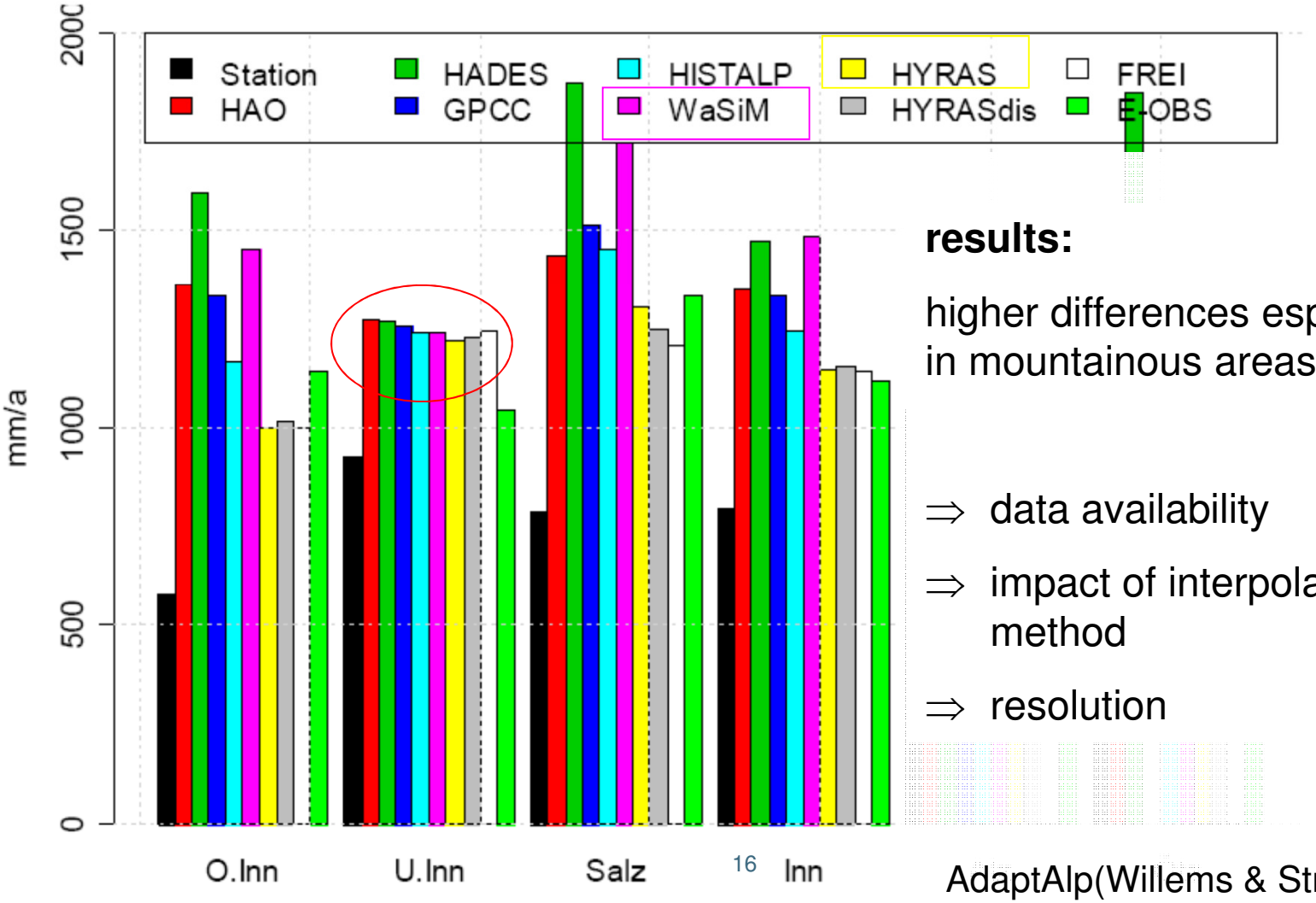
Tab. 19: WHM Oberer Main, Gütewerte der Validierung im Zeitraum 01.01.1986 – 31.10.2006, Simulation mit vorgeschaltetem Talsperrenmodell

TG	Pegel	Gewässer	Kat.	Zeitraum	MQrel	NSClin	NSClog	EVlin	EVlog	R2	KGElin	KGElog	MoNSClin	MoNSClog	Bemerkung
2	Kemmern	Main	1	01.01.1986-31.10.2006	-4.25	0.92	0.94	0.92	0.94	0.93	0.87	0.94	0.95	0.97	
3	Leucherhof	Baunach	2	01.01.1986-31.10.2006	-10.4	0.82	0.84	0.83	0.85	0.84	0.76	0.81	0.87	0.88	
4	Heinersdorf	Rodach	2	01.01.1986-31.10.2006	-0.98	0.83	0.87	0.83	0.88	0.83	0.84	0.84	0.92	0.94	
5	Coburg	Itz	3	01.01.1986-31.10.2006	-4.65	0.89	0.87	0.89	0.87	0.89	0.9	0.93	0.94	0.92	HW-Rückhalt
6	Schwürbitz	Main	2	01.01.1986-31.10.2006	-8.21	0.92	0.93	0.93	0.93	0.94	0.82	0.94	0.94	0.95	
7	Horb	Steinach	3	01.01.1986-31.10.2006	-6.44	0.87	0.9	0.87	0.9	0.9	0.75	0.94	0.92	0.93	
8	Unterlangenstadt	Rodach	2	01.01.1986-31.10.2006	-6.31	0.92	0.9	0.92	0.91	0.93	0.85	0.9	0.95	0.94	Trinkwasserentnahme
9	Neukenroth	Hasslach	3	01.01.1986-31.10.2006	-12.22	0.9	0.84	0.9	0.87	0.9	0.87	-0.61	0.93	0.89	Inhomogene Zeitreihe
10	Steinberg	Kronach	3	01.01.1986-31.10.2006	-9.53	0.88	0.78	0.88	0.81	0.88	0.86	0.31	0.92	0.89	
11	Wallenfels	Wilde Rodach	3	01.01.1986-31.10.2006	4.7	0.87	0.81	0.87	0.82	0.88	0.88	0.48	0.93	0.89	
12	Untersteinach	Schorgast	2	01.01.1986-31.10.2006	-3.15	0.8	0.85	0.8	0.85	0.83	0.74	0.92	0.89	0.91	

Choosing the right observation data set

Comparison of different observation data sets

precipitation *(yearly sums 1971-1990)*



results:

higher differences especially in mountainous areas

⇒ data availability

⇒ impact of interpolation method

⇒ resolution

AdaptAlp(Willems & Stricker, 2011)

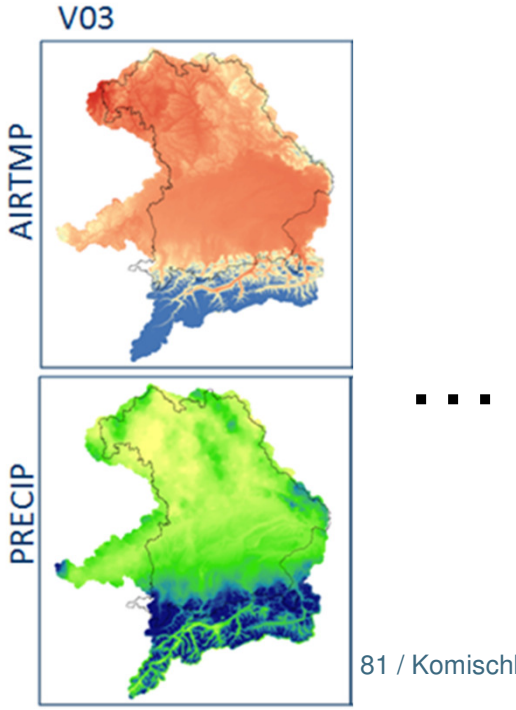
Choosing the right observation data set

- Since 2001 / north of the Danube:
  meteorological stations, interpolated within WaSiM, **corrected** precipitation

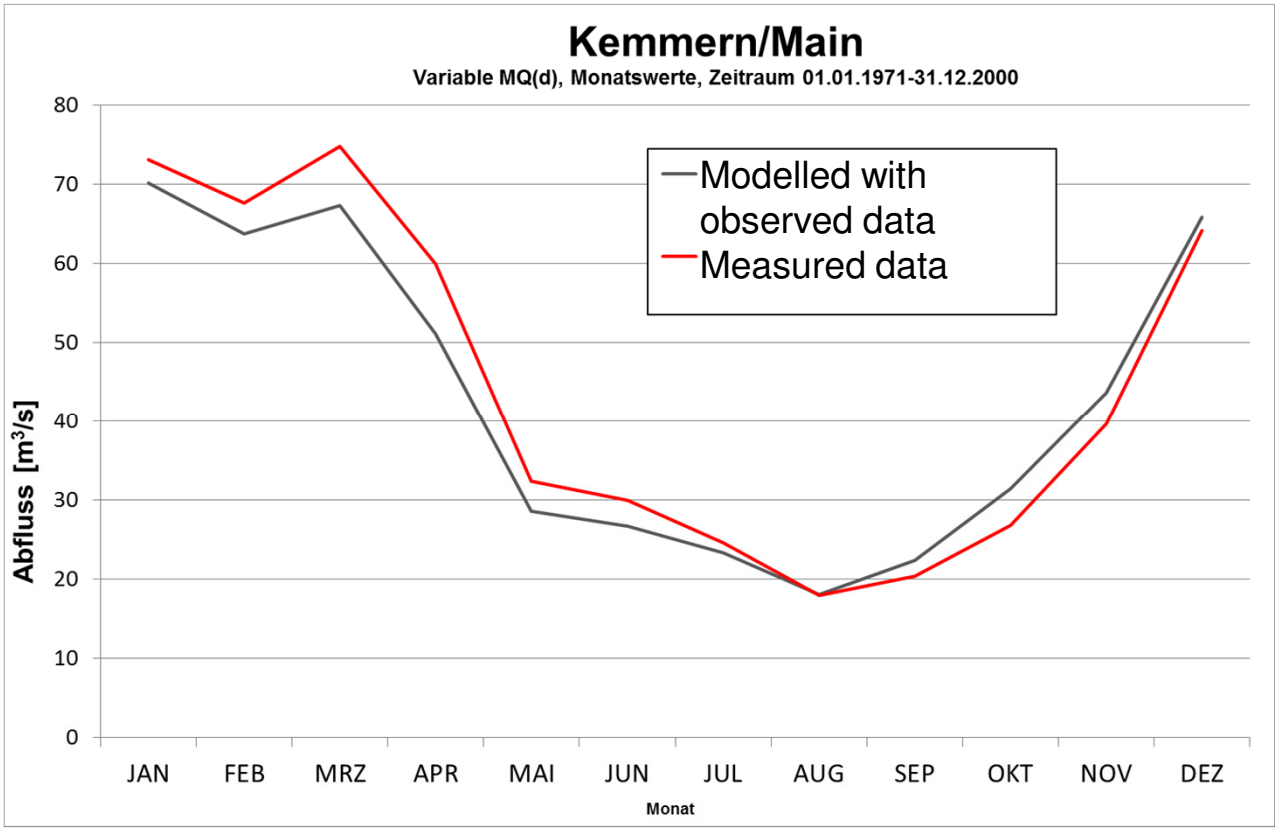
- Southern tributaries to the Danube:
  meteorological stations, interpolated within WaSiM including regional superposition with **uncorrected** precipitation

- Update of hydrological models:
  Already interpolated, observed raster data sets (HYRAS-DWD: **uncorrected precipitation**, temperature, humidity) and external interpolated wind & sunshine duration (Willems & Stricker 2013, i.A. LfU)

⇨ One observation dataset for all models



⇨ Results with 30 years observed data



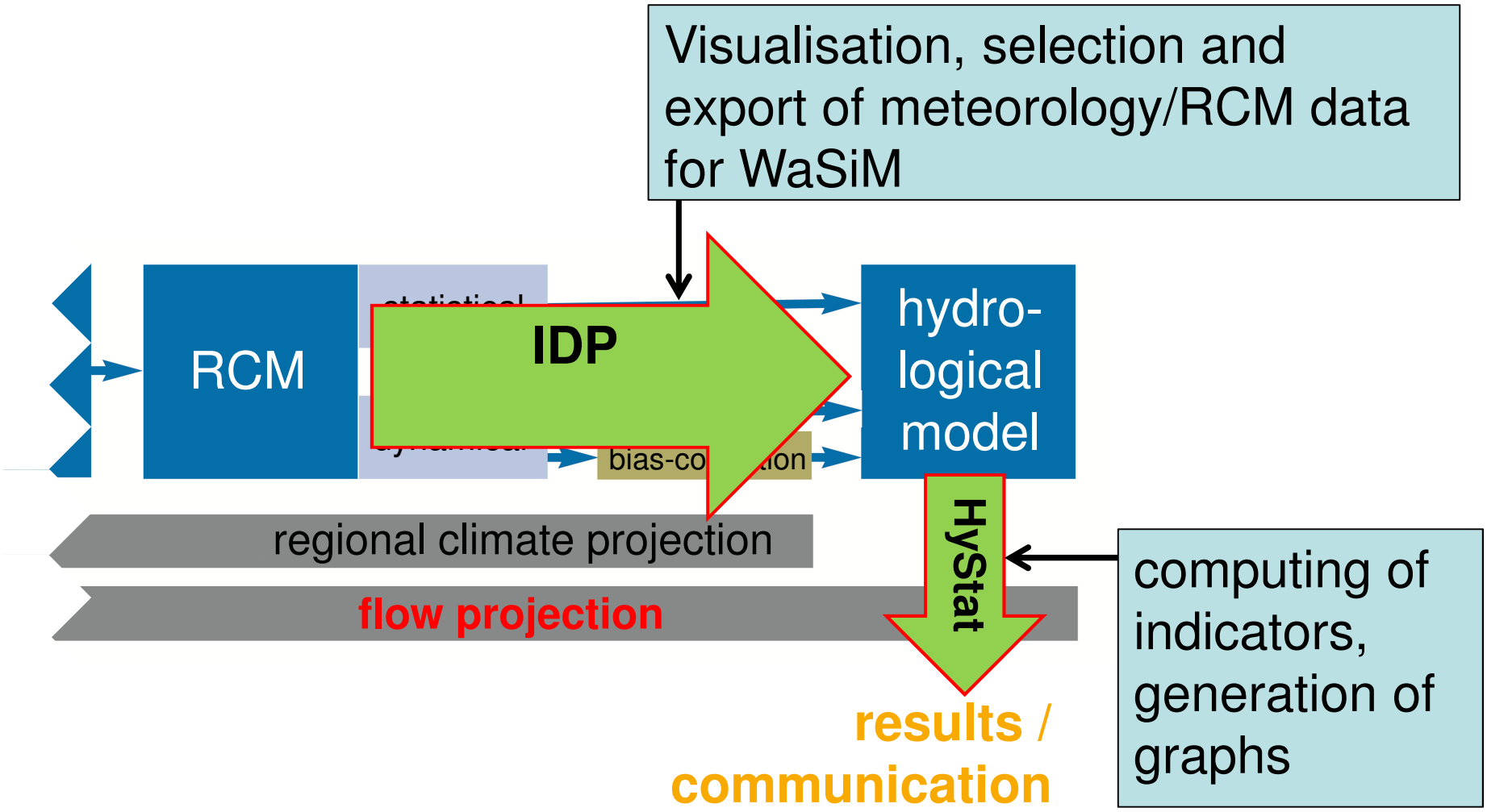
⇨ For Bavaria:

Modelled datasets of at least 30 years at about 400 gauges in 19 hydrological models

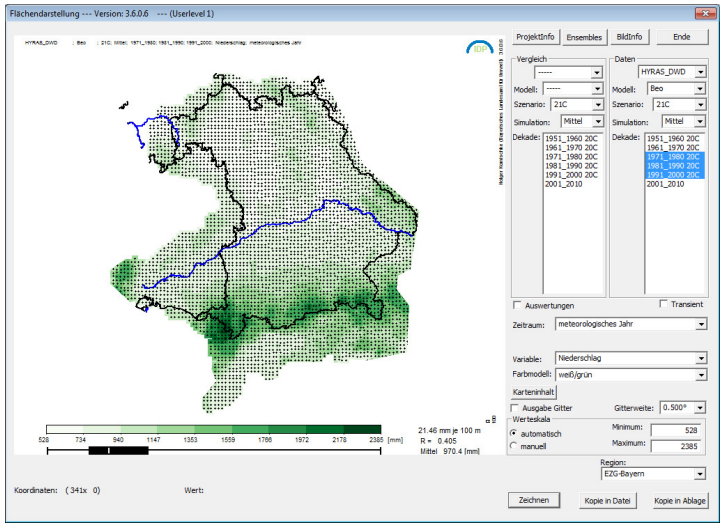
Monthly mean flow measured and modelled with observational data at the gauge Kemmern for 1971-2000

But having the model is not everything
- WaSiM-ETH interfaces at the LfU -

The need to fit WaSiM into the model chain

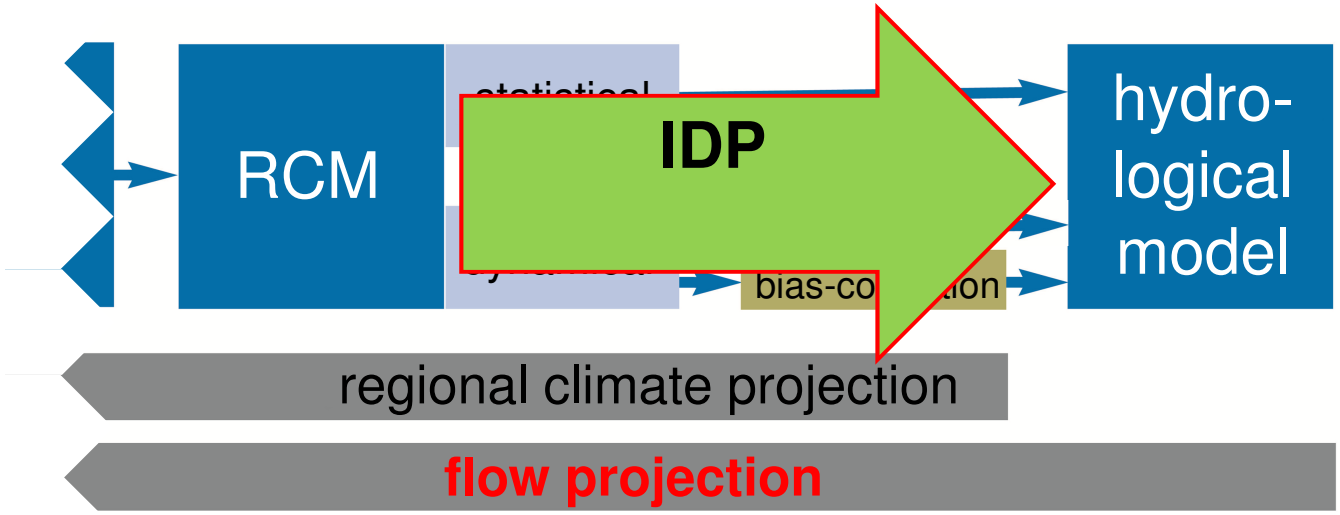


Interfaces for WaSiM:



Meteorological input data - IDP:

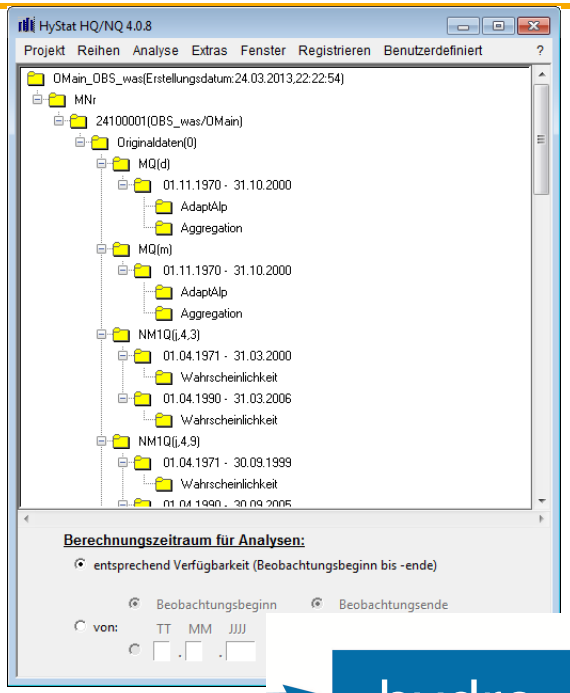
- all measured and RCM data we used so far, basic visualisation and analysis
- selection and output in WaSiM-ETH format

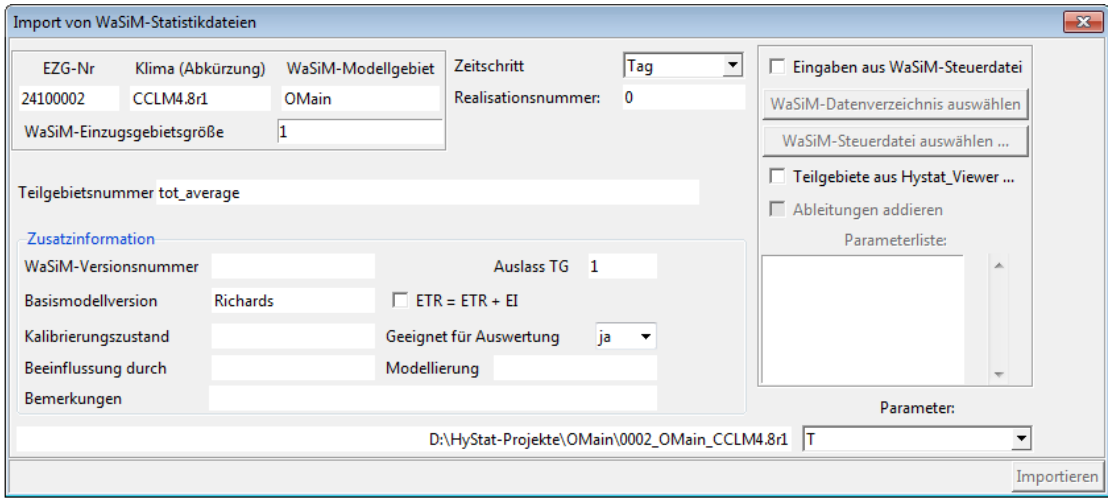


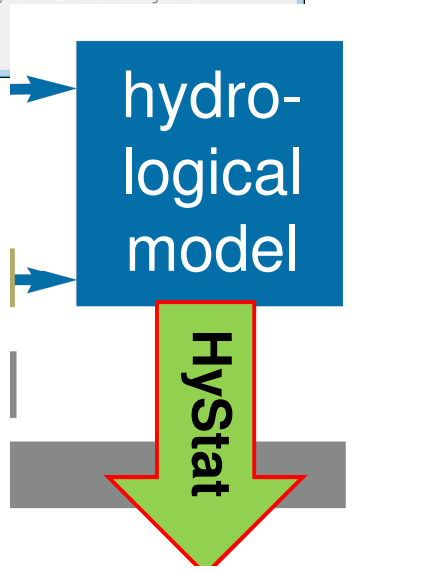
Interfaces for WaSiM:

Analysis of the modelling results - HyStat

- import of model results per gauge and projection: flow, meteorology, flow components, ETR/ETP
- statistical analysis, computing of indicators and graphs
- based on software for the hydrological service







runoff indicators

Present topics on our mind

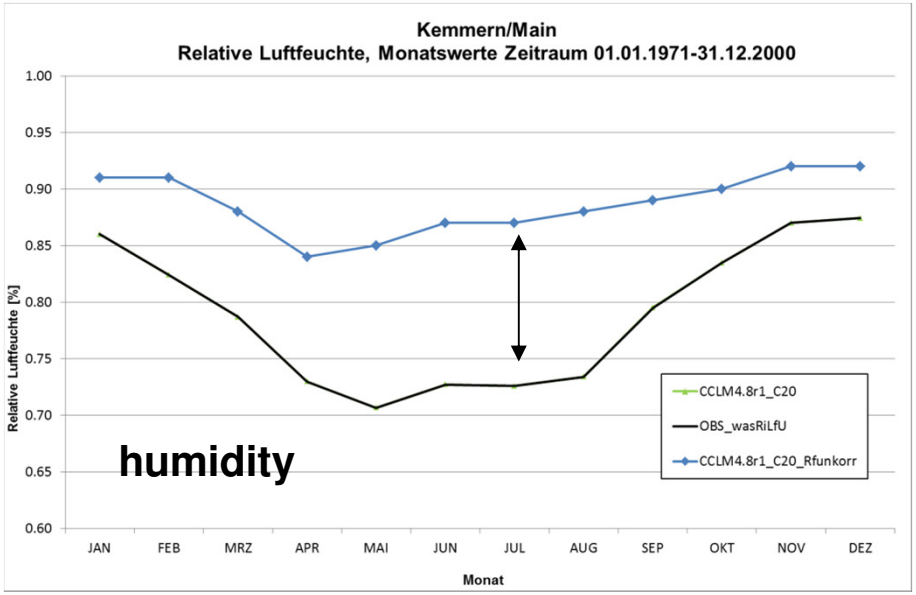
Present topics:

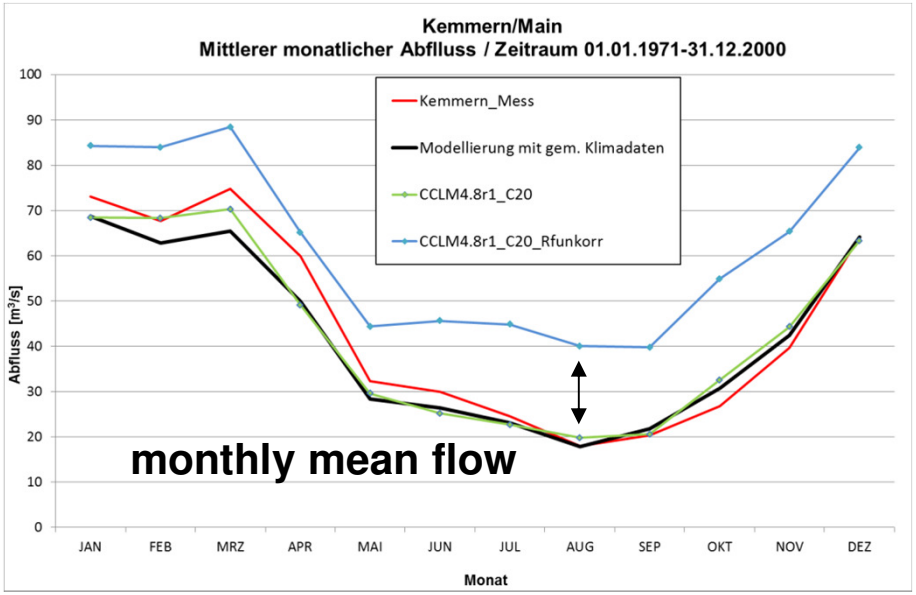
- Modelling with climate projections (some examples later)
- Due to bias-correction – sensitivity of the hydrological model to meteorological input

Sensitivity of the hydrological model

- **e.g. meteorology / humidity (⇨ ETR / flows)**

⇨ How does my hydrological model react to bias in climate projections?





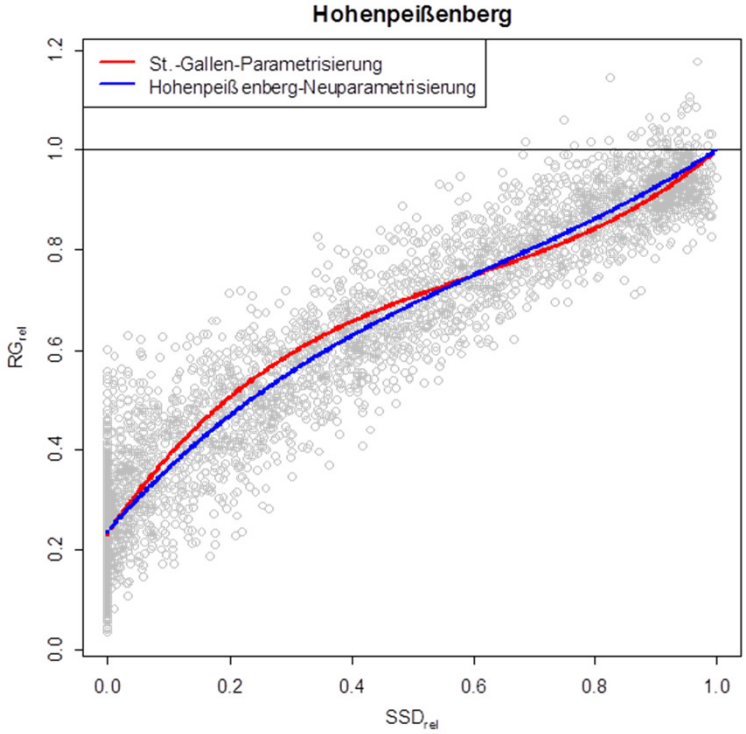
Bias humidity between 5 and 15 % ⇨ high differences in flow

⇨From where on do I have to apply BC? →sensitivity and plausibility hydrological model

⇨How far can you apply BC?

Present topics:

- Modelling with climate projections (examples later)
- Due to bias-correction – sensitivity of the hydrological model to meteorological input
- Internal conversion of sunshine duration to global radiation



Relationship between relative sunshine duration and relative global radiation at the station Hohenpeißenberg, characterized through the WaSiM-standard parameterisation and a new parameterisation based on measured values

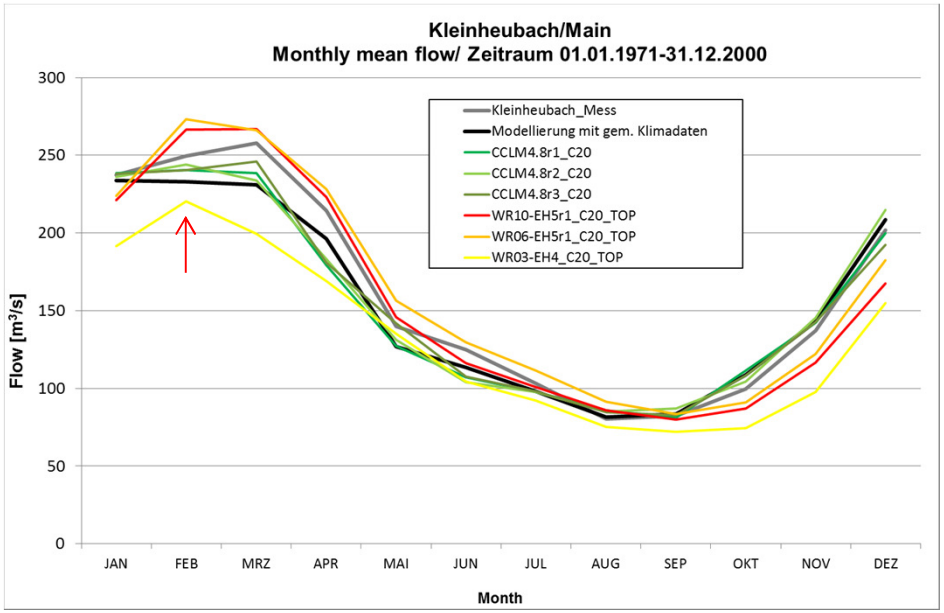
⇨ Standard parameterisation for conversion of sunshine duration seems to overestimate global radiation for Bavaria

(Willems & Stricker 2013, i.A. LfU)

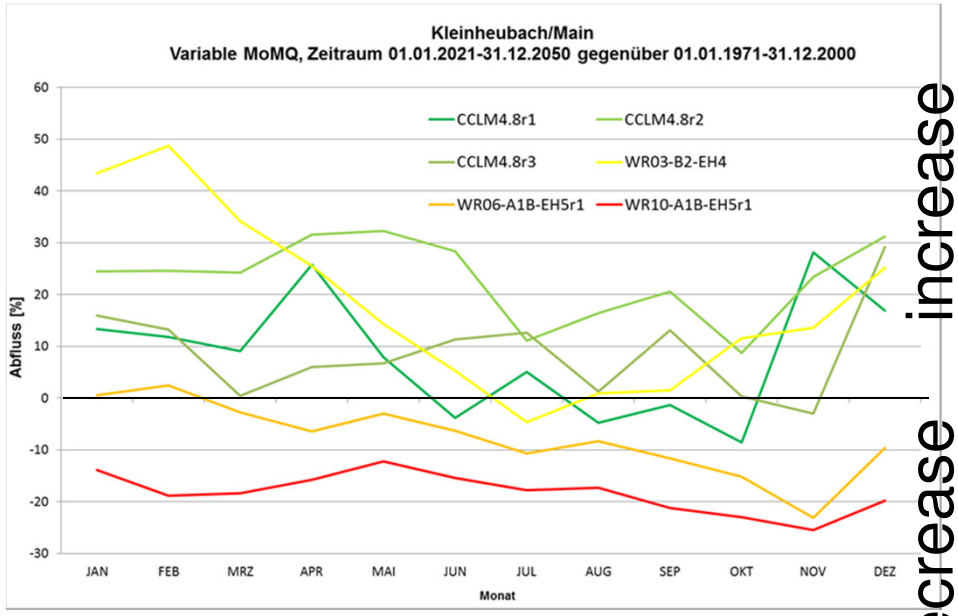
Example for results of hydrological modelling coupled with regional climate scenarios

Examples for results RCM and hydrological model

Plausibilty of the monthly mean flow for 1971-2000



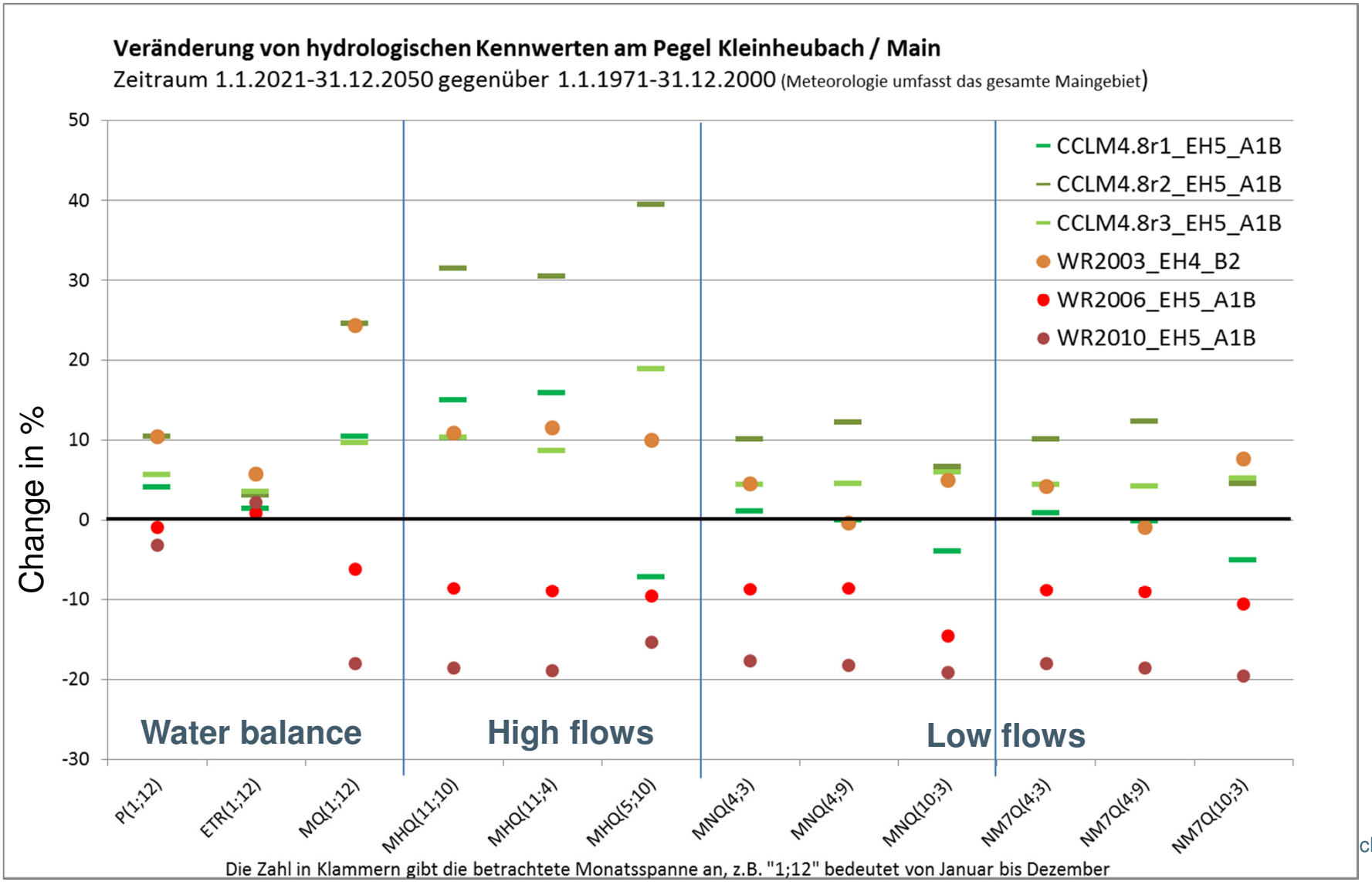
Changes in the monthly mean flow 2021-2050 versus 1971-2000 in %



increase

decrease

Changes in the hydrology of the Main catchment



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WaSiM- Workshop 15.10.2013 LfU, Augsburg

- Organised and hosted by LfU
- 14 Participants
- Reports by WaSiM-users, suggestions for improvements to WaSiM, possibilities/options for implementation, discussion of some specific topics

Results of the WaSiM-WS 15.10.2014

- Suggestions for improvements **(examples):**
  - **Interpolation of meteorological input:** Using background fields (Hintergrundfelder) e.g. for wind
  - **Conversion of sunshine duration into global radiation:** Parameterisation of the conversion procedures in a way that is transparent for the user
  - **Snow model, module:** Need for improved modelling of snowmelt and snow accumulation
  - **Evapotranspiration:** Interest in alternative evaporation approaches (i.e. fewer input variables)
  - **Reservoirs:** Option of implementing the point in time at which a reservoir goes into operation
- **Discussion (example)**
  - **Special parameterisation:** Can a model be expected to model do “everything” or is it acceptable to have different parameterisations for different specific questions (e.g. peak flood flow)?

Thank you for your attention!