Flächendifferenzierte Modellierung des Wasserhaushalts im Nationalpark Berchtesgaden und Analyse der Schneedynamik

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Modellierung Wasserhaushalt Nationalpark BGL

Ziele

- Berechnung & Abschätzung der Wasserhaushaltskomponenten in der Region des NP mittels hydrologischem Modell WaSiM

  NP: 208 km² , EZG: 470 km²

  Wimbach, Klausbach, Königsseer-, Ramsauer- und Bischofswiesener Ache

- Prozessverständnis Interaktion Oberflächenwasser & Grundwasser & Schneedynamik im NP

- Verbesserung der Schneemodellierung in WaSiM:

  Integration von AMUNDSEN

- Validierung des Schneemodells (Stationsdaten, MODIS)

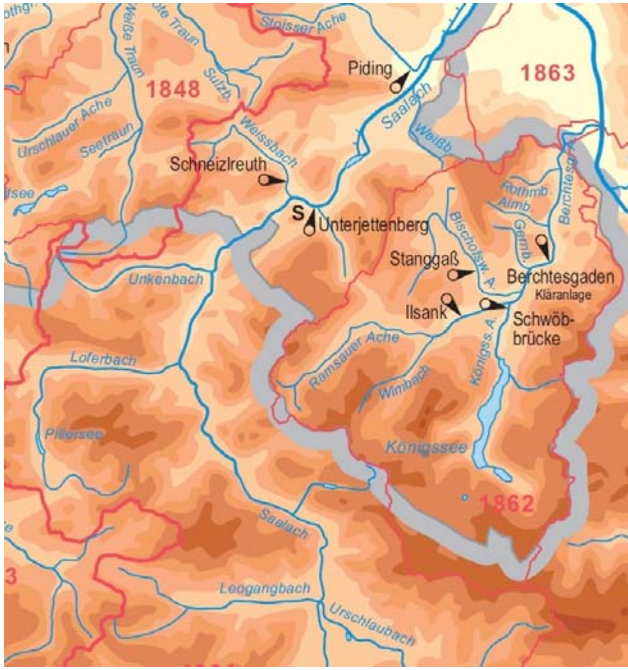
- Erwartete Änderung des Wasserhaushalts unter Klimaänderung

Nationalpark Berchtesgaden

- Höchste Erhebung: Watzmann 2713 m
  ≈2100 m Höhengradient
- Verkarstete Hochflächen,
  20% Fels/Schuttflur, 44% Wald
- Jahresmitteltemperatur
  7°C (Königsee) bis -2°C (Watzmann)
- Mittlerer Jahresniederschlag
  Täler: ≈1500 mm, Hochlagen: ≈2600 mm
  Niederschlagsmaximum im Juli
- Mittlere Schneehöhen:
  Täler: 50 cm, Hochlagen: 3-5 m
- Vegetationszeit:
  Täler: 160 Tage, Hochlagen: 60 Tage

Nationalpark Berchtesgaden

Lage und statistische Hauptwerte der Abflusspegel



[m³/s]	HQ	MHQ	MQ	MNQ	NQ
Berchtesgadener Ache	247	125	16,3	4,87	2,9
Ramsauer Ache	66,3	35,6	5,19	1,93	0,6
Bischofswiesener Ache	54,5	18,1	1,52	0,645	0,31
Königsseer Ache	109	58,7	8	1,51	0,33

Stillgewässer: Königsee, Obersee, Mittersee, Grünsee, Funtensee, Schwarzensee, Seeleinsee, Blaue Lache, Laubseelein

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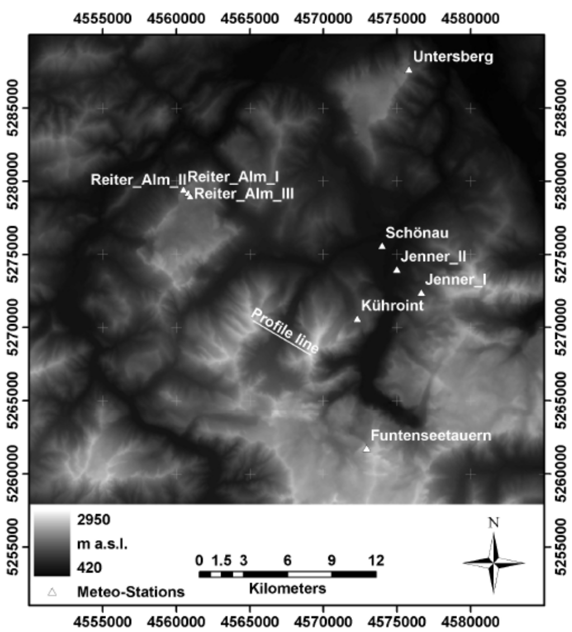
Nationalpark Berchtesgaden

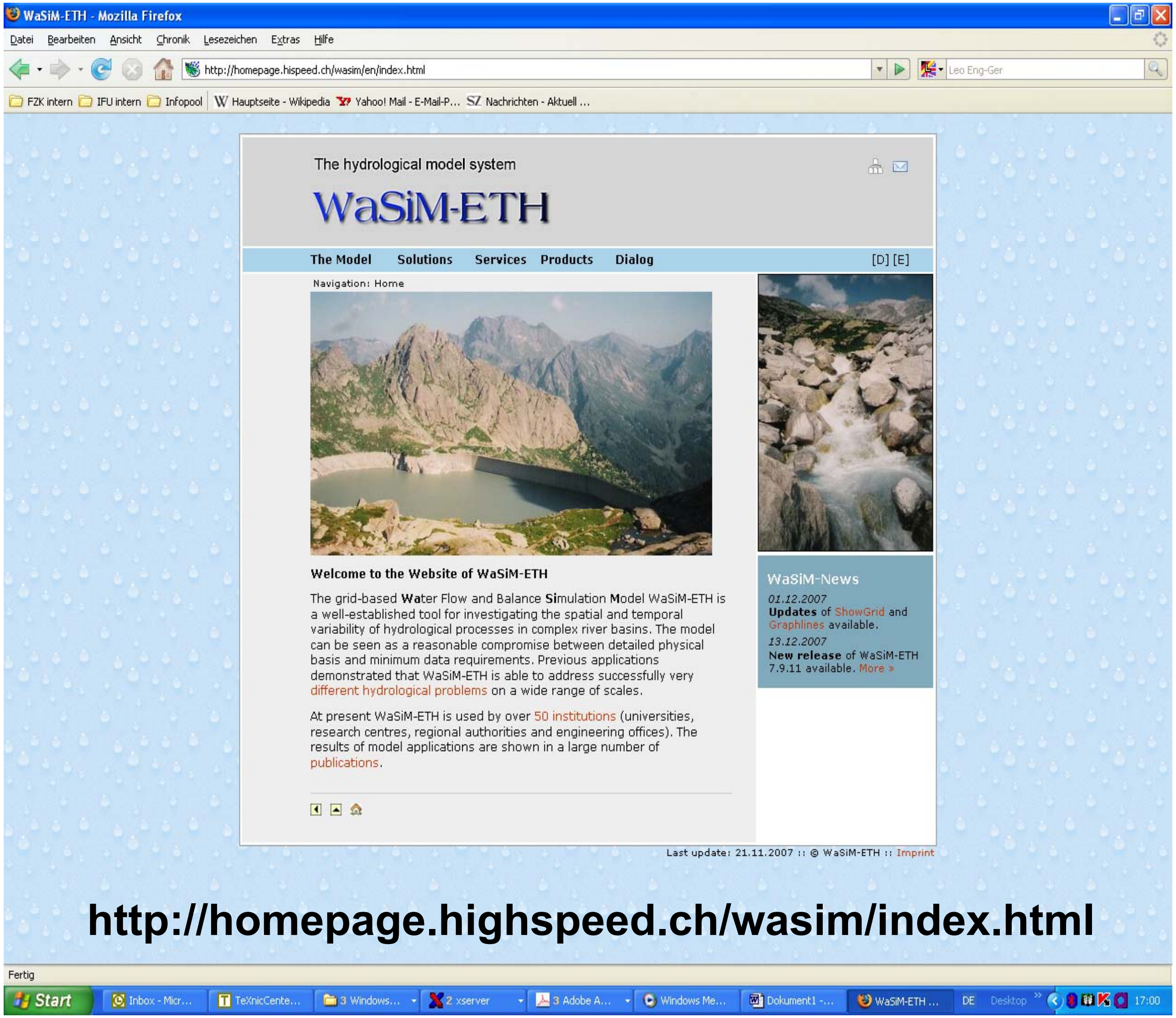
Lage der meteorologischen Stationen



Station	Altitude [a.s.l.]	Easting [m]	Northing [m]	Parameters	Resolution
Reiter Alm I	1755 m	4 560 494	5 279 436	WS, WS_{max}, WD	10 min
Reiter Alm II	1670 m	4 560 835	5 279 235	T, T_{S0}, T_{S20}, T_{S40}, T_{S60}, T_{SS}, H, SH	10 min
Reiter Alm III	1615 m	4 560 950	5 278 982	T, H, GR, RR, P, SH	10 min
Kuehroint	1407 m	4 572 314	5 270 625	T, H, GR, RR, WS, WD, P, SH	10 min
Funtenseetauern	2445 m	4 572 939	5 261 755	T, H, WS, WD	10 min
Jenner I	1200 m	4 576 659	5 272 417	T, T_{S0}, T_{S20}, T_{S40}, T_{SS}, H, SH	10 min
Jenner II	660 m	4 575 000	5 273 988	T, H, P	10 min
Schoenau	617 m	4 573 987	5 275 597	T_{005}, T, H, GR, DR, SS, WS, WD, P, AP	10 min
Untersberg	1776 m	4 575 822	5 287 649	T, H, WS, WS_{max}, WD, P	30 min

WS = wind speed
WS_{max} = maximum wind speed
WD = wind direction
T = temperature
T_{005} = temperature (0.05 m)
T_{S0} = snow temperature (0.0 m)
T_{S20} = snow temperature (0.2 m)
T_{S40} = snow temperature (0.4 m)
T_{S60} = snow temperature (0.6 m)
T_{SS} = snow temperature (snow surface)
H = humidity
SH = snow height
SS = sunshine duration
GR = global radiation
DR = direct radiation
RR = reflected radiation
P = precipitation
AP = air pressure at sea level

Flächendifferenzierte hydrologische Modellierung



http://homepage.highspeed.ch/wasim/index.html

Distributed Hydrological Model WaSiM

- Well-established tool for investigating the spatial and temporal variability of hydrological processes in complex river basins.
- Reasonable compromise between detailed physical basis and minimum data requirements.
- Previous applications demonstrated that WaSiM-ETH is able to address successfully very different hydrological problems on a wide range of scales.
- Is used by over 50 institutions (universities, research centres, regional authorities and engineering offices).

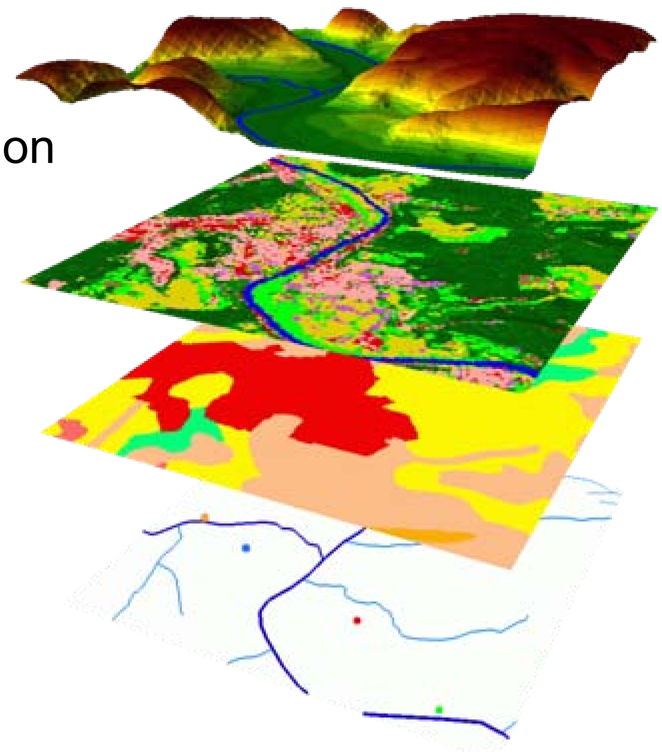
Distributed Hydrological Model WaSiM

Physically based algorithms for vertical water fluxes & groundwater:
- Evapotranspiration: soil and vegetation specific (Monteith)
- Flow through unsaturated zone (Richards)
- Suction head & hydraulic conductivity (van Genuchten)
- 2-dim groundwater model dynamically coupled to unsaturated zone

Conceptual approaches for lateral runoff aggregation
- Traveltime approach folded with linear storage
- Discharge routing: cinematic wave

Snow: day-degree approach

Setups so far at IMK-IFU
- spatial resolution: 90x90m² till 1x1 km²
- temporal resolution: hourly-daily
- subdivision into sub-catchments



Distributed Hydrological Model WaSiM

Data requirements

- **Geographical data:**
  minimum: digital elevation model, land use and soil grid →
  further spatial distributed data (slope, river network, subcatchments,…)

- **Meteorological data**
  minimum: temperature and precipitation
  standard: global radiation, wind speed, relative humidity
  ⇨ require spatial interpolation on regular WaSiM-grid

- **Hydrological Data**
  river discharge time series
  water management data (e.g. abstractions)
  if available: groundwater heads, tracer, aquifer properties
  (hydraulic conductivity, porosities, colmation resistance, aquifer thickness)

Distributed Hydrological Model WaSiM

Special features (incomplete):

- Variable cell sizes
- Dynamic simulation of vegetation development (LAI dynamics)
- Advanced landuse table
- Advanced soil table
- **Macropore runoff**
- Exfiltration and re-infiltration of groundwater
- Irrigation management
- Considering (artificial) drainage
- Considering ponds
- **Modelling of glacier runoff**
- Considering reservoir management
- Considering external abstractions and inflows
- Online coupling with external models
- Coupling of sequential model runs
- Coupling of substance transport (⇨ tracer) with water flow

Water Balance Modelling NP BGL

- **Subcatchments**
  Wimbach, Klausbach, Königseer, Ramsauer, Bischofswiesern Ache

- **Resolution**
  Δx=50-500m, Δt=1h

- **Approach**
  Richards-eq., Penman-Monteith, 2-dim groundwater model, etc.
  New snow module

- Calibration/validation: from 1990 on

- Validation of areal snow cover dynamics using MODIS satellite data

- Finally: **climate change impact analysis** (→ RCM driven WaSiM)

Distributed Hydrological Model WaSiM

Snow accumulation

$$p_{snow} = \frac{T_{R/S} + T_{trans} - T}{2\,T_{trans}}$$

Snow melt

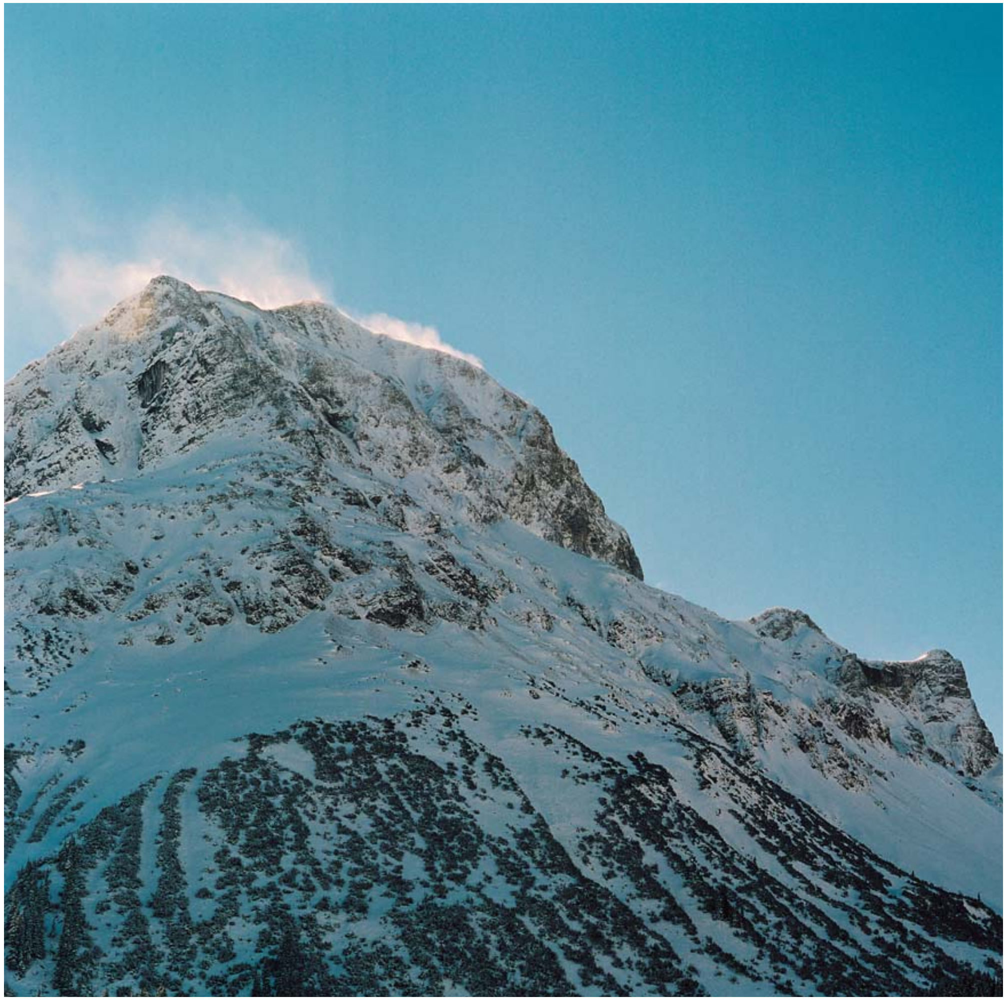
- Temperature index approach

$$M = c_0 (T - T_{0,m}) \frac{\Delta t}{24} \left[\frac{mm}{°C\,d} \right]$$

- Temperature-wind approach

$$M = (c_1 + c_2 u)(T - T_{0,m}) \frac{\Delta t}{24} \quad \left[\frac{mm}{°C\,d} \right]$$

- Combination approach



Verbesserung der Schneemodellierung in WaSiM

Implementierung des Schneemodells AMUNDSEN
***(Alpine MUltiscale Numerical Distributed Simulation ENgine)* in WaSiM**

⇨ **Berücksichtigung von**

- Sublimation
- Beschattung und Strahlung (incl. multiple Reflexionen, Geländereflexionen abhängig von der Oberfläche (Schnee – nicht Schnee), Bewölkung
- Einfluss des Bestandes (Interzeptionsprozesse, Sublimation)
- Lateraler Schneetransport (gravitative Rutschungen)
- Volle Energiebilanz der Schneedecke (Strahlungsbilanz, turbulente Flüsse, Bodenwärmestrom)

Hydrologische Modellierung:

Beispiel

Ammer Einzugsgebiet

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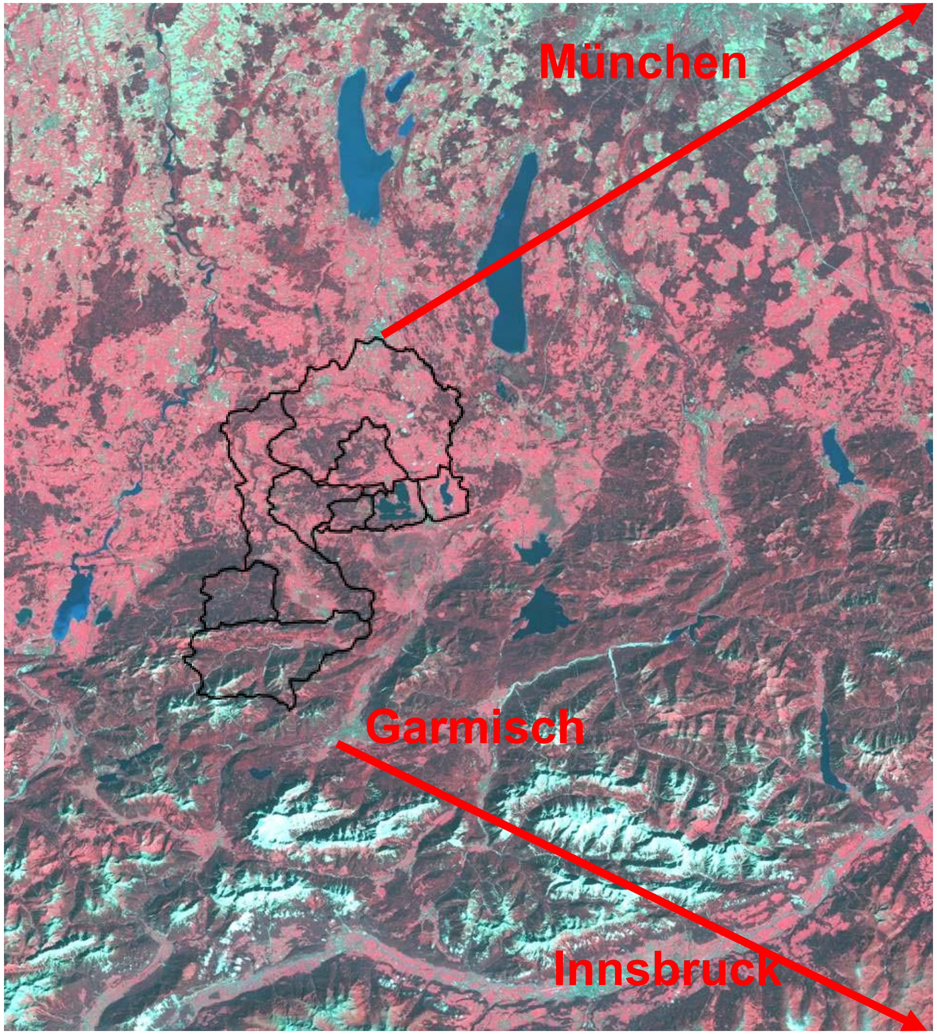
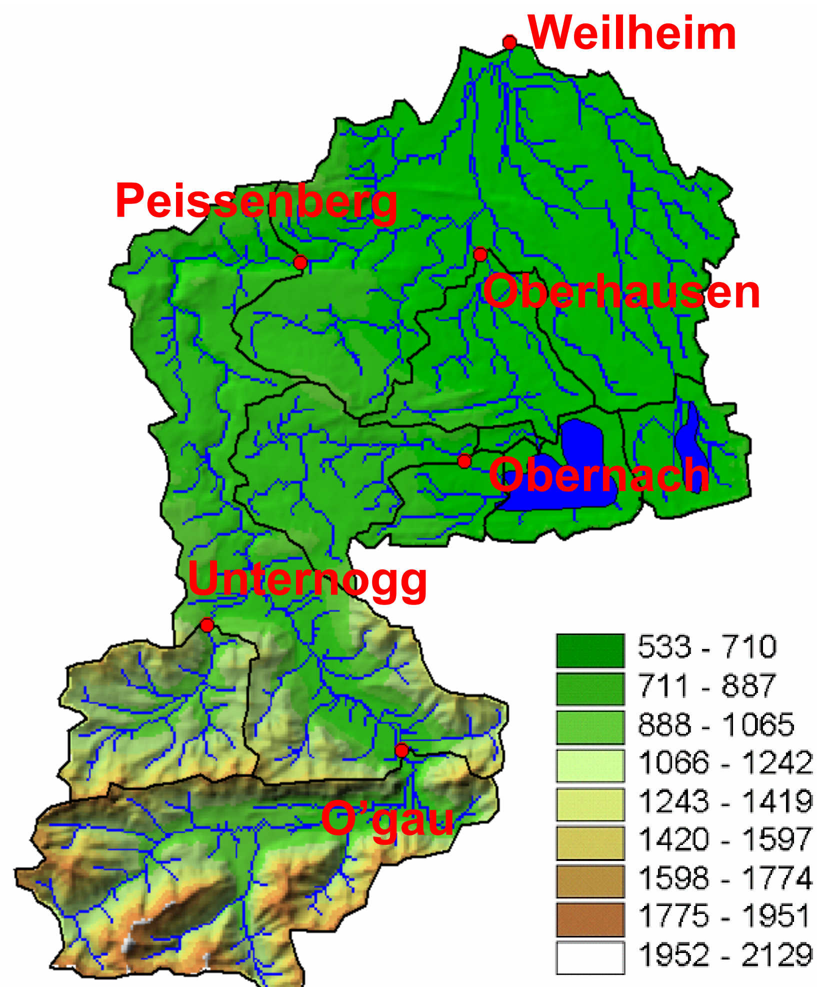
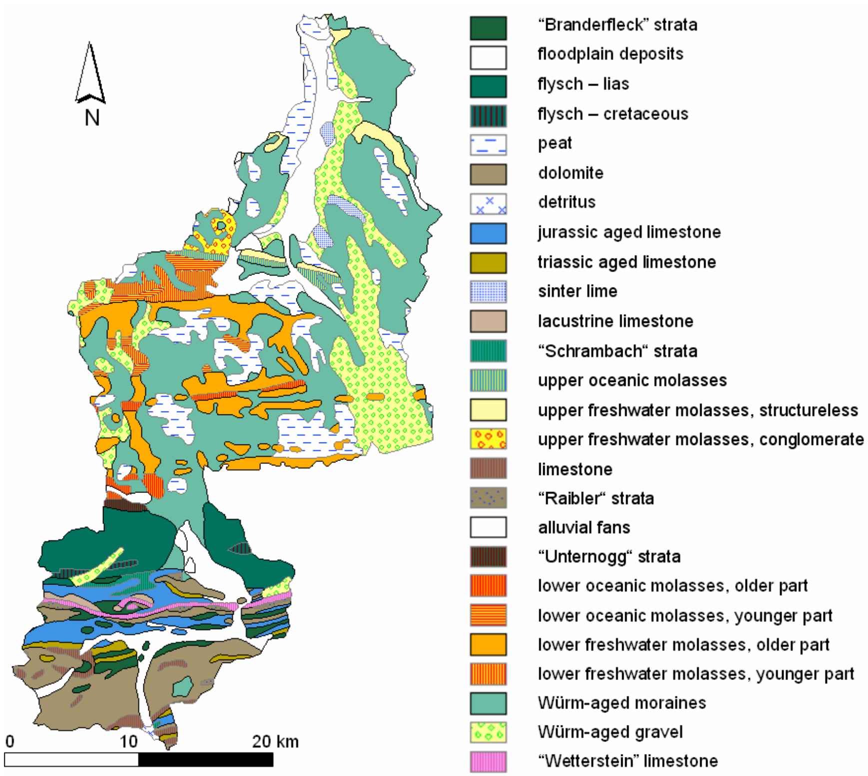
Ammer Einzugsgebiet

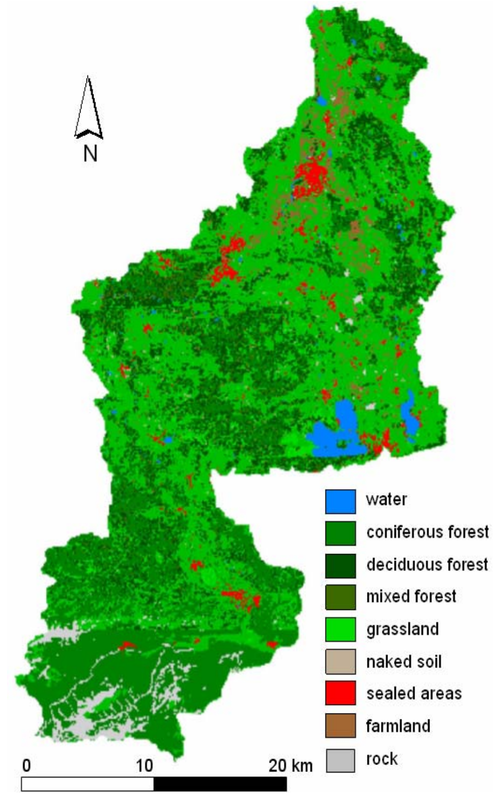




Modellauflösung Δx= Δy=100m

Ammer Einzugsgebiet





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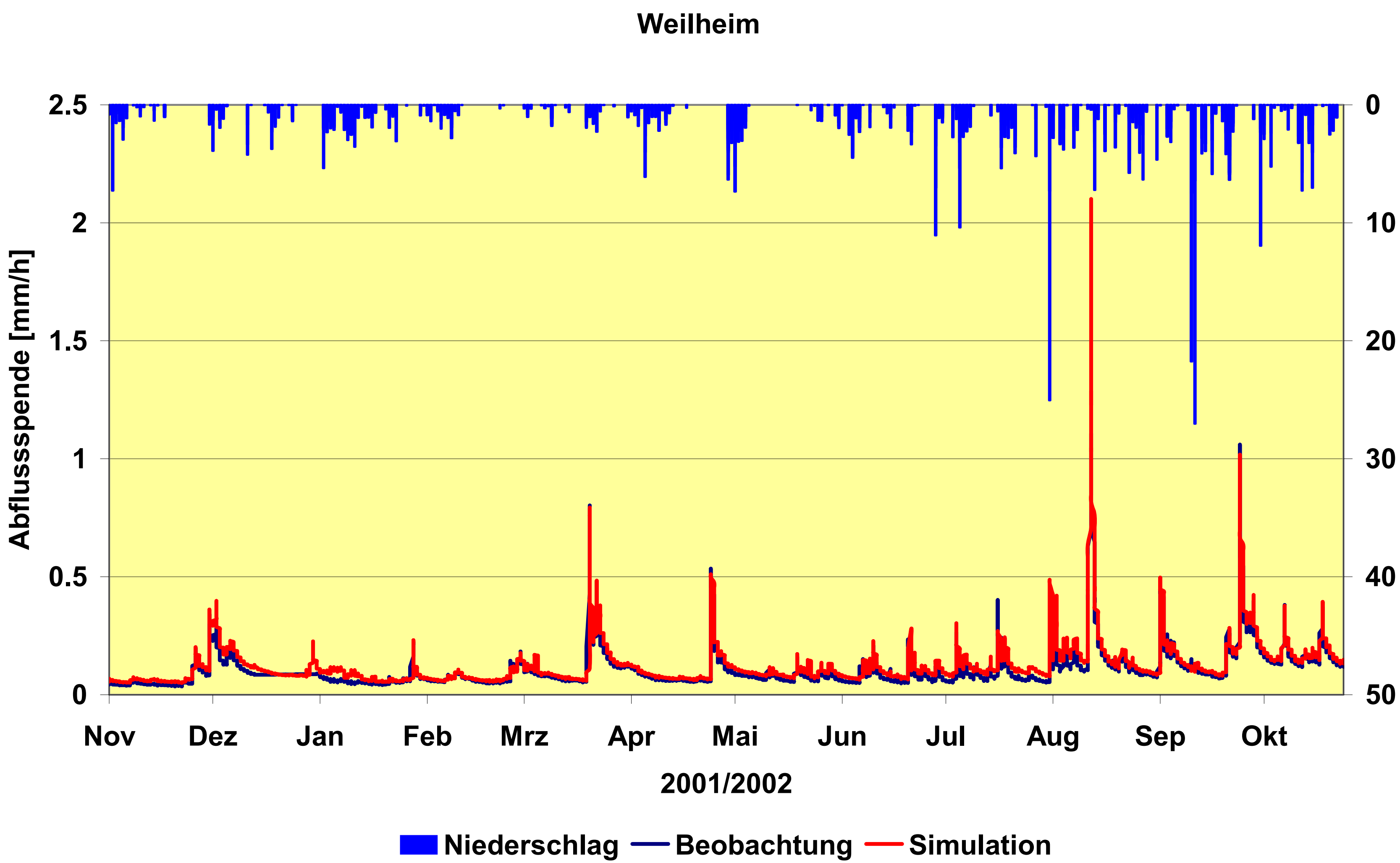
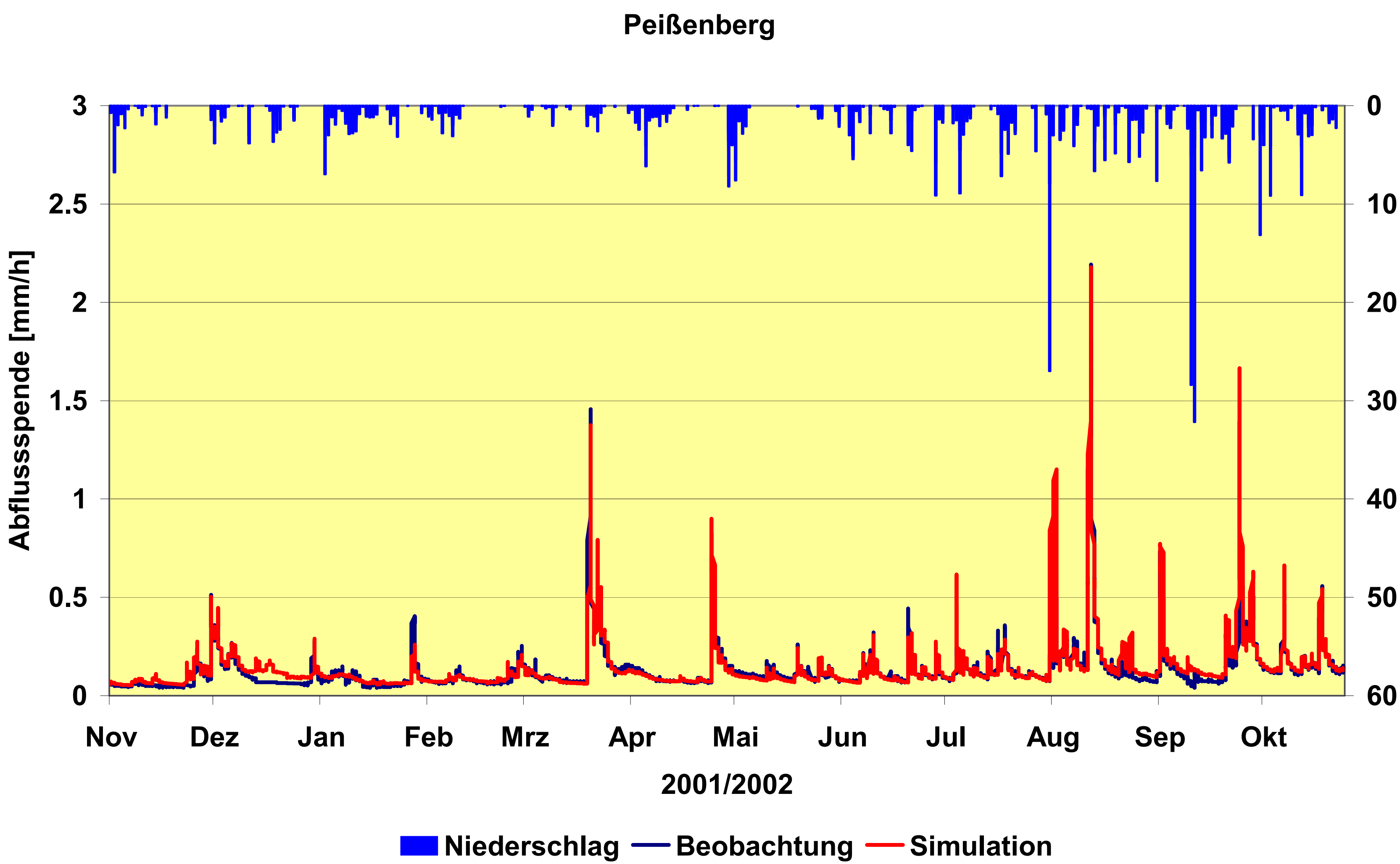
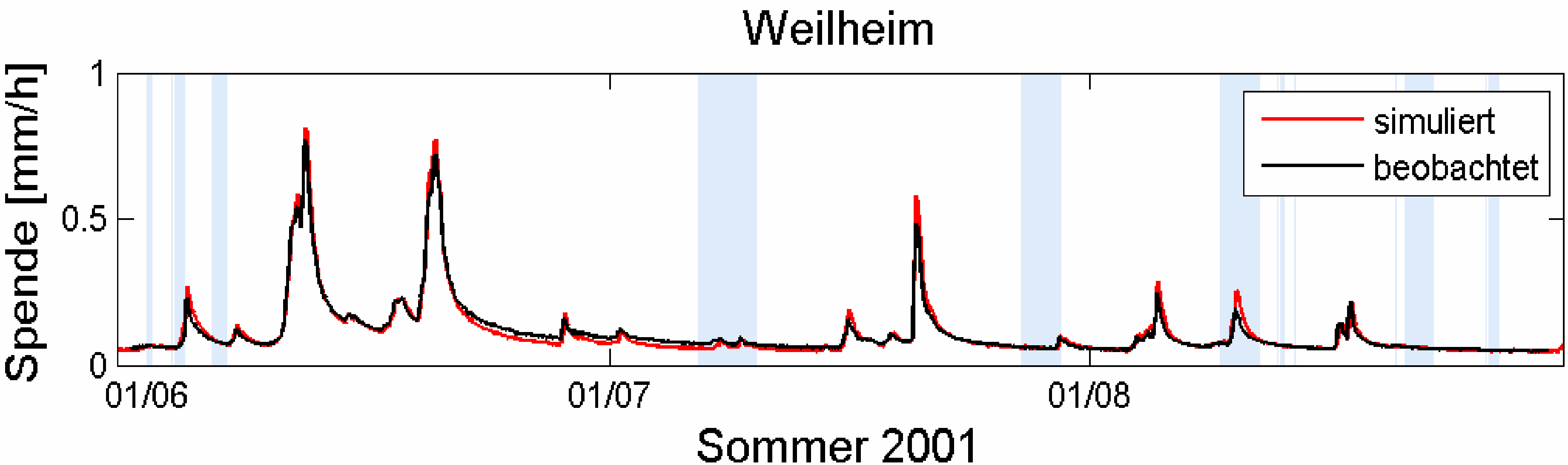


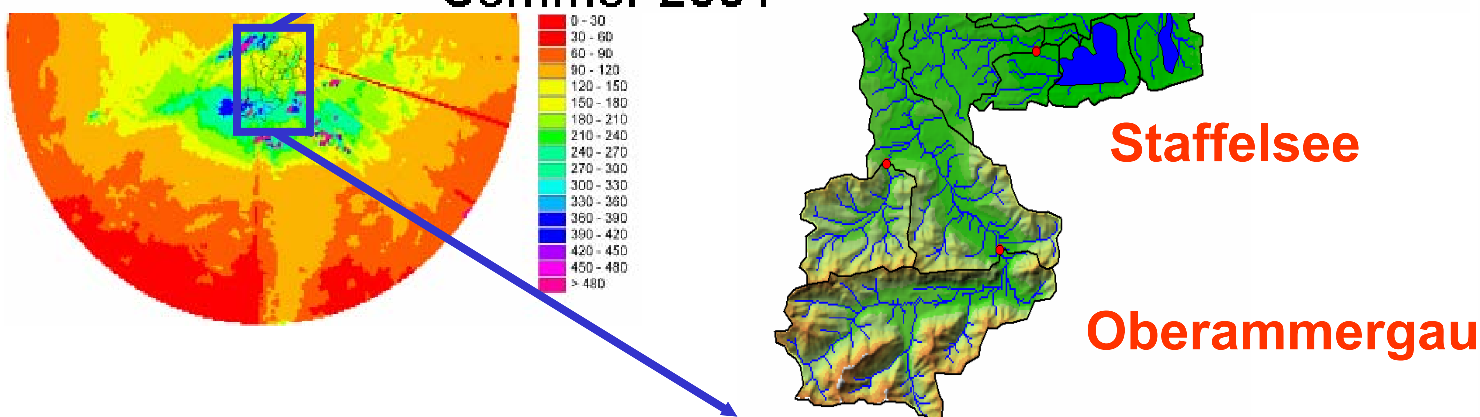
Ammer Einzugsgebiet



Ammer Einzugsgebiet

Erfassung der räumlichen Niederschlagsvariabilität im alpinen Terrain zur verbesserten Abfluss-Simulation

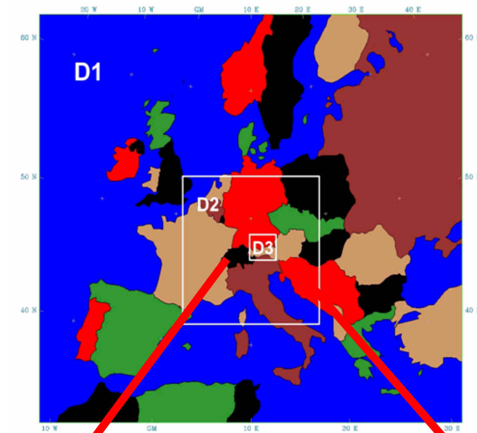




Regionale Klima-Hydrologie Modellierung

- Temperatur
- Niederschlag
- Wind
- Relative Feuchte
- Globalstrahlung

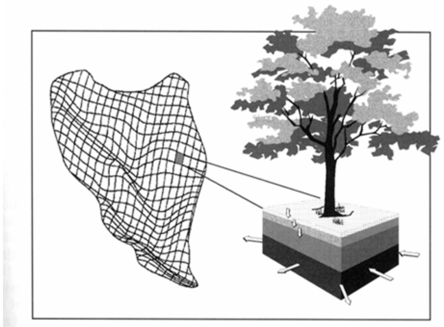
3-dim. atmosphärisches Modell



100x100km² → 4x4 km²

Hydrologisches Modell

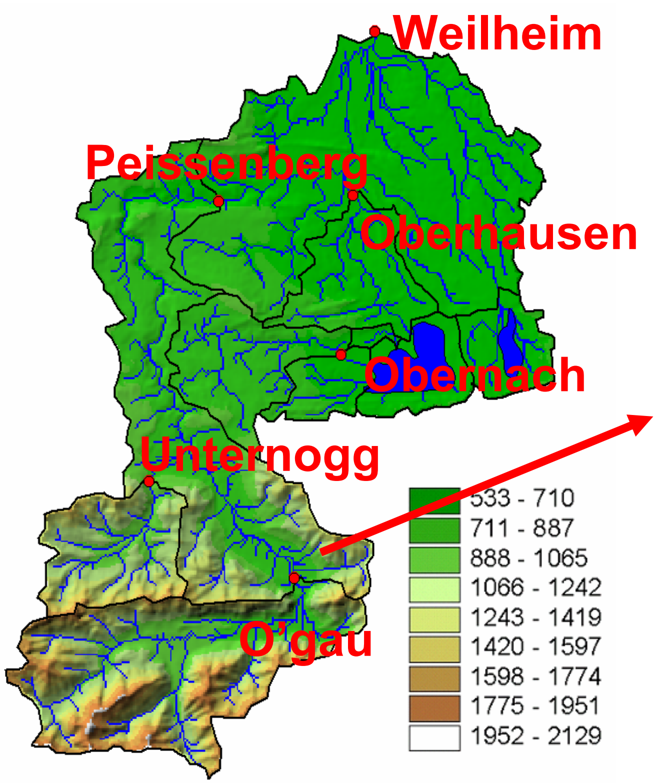
- Orographie
- Landnutzung
- Bodeneigenschaften
- Aquifereigenschaften
- Flussnetz



100x100 m² Auflösung

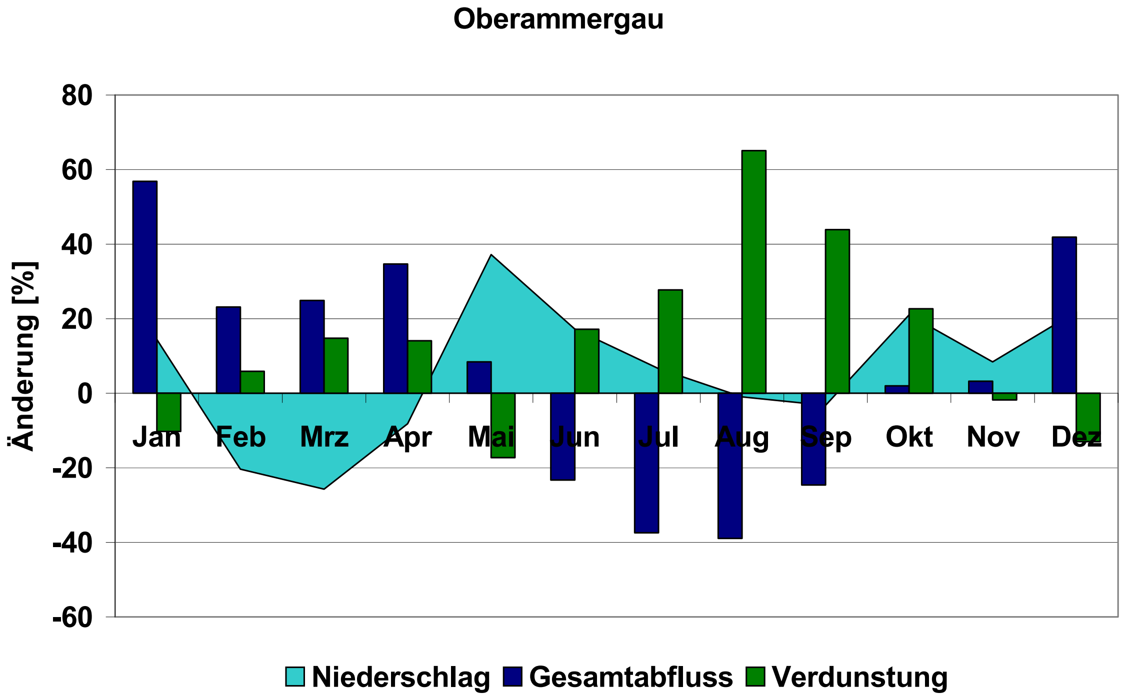
Evapotranspiration Infiltration Abfluss Grundwasser

Klimaänderung & Wasserverfügbarkeit Ammer



Modellkaskade ECHAM4 – MM5 – WaSiM

Änderung 1990-99 vs. 2030-39

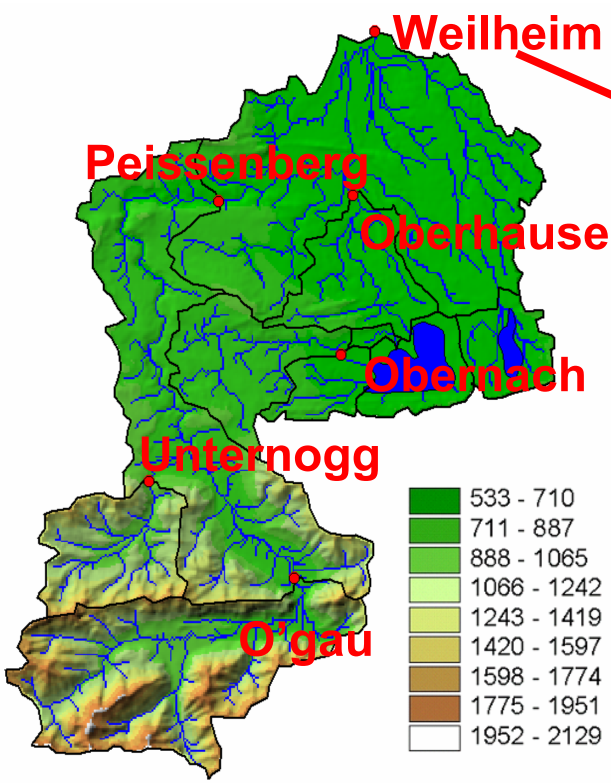


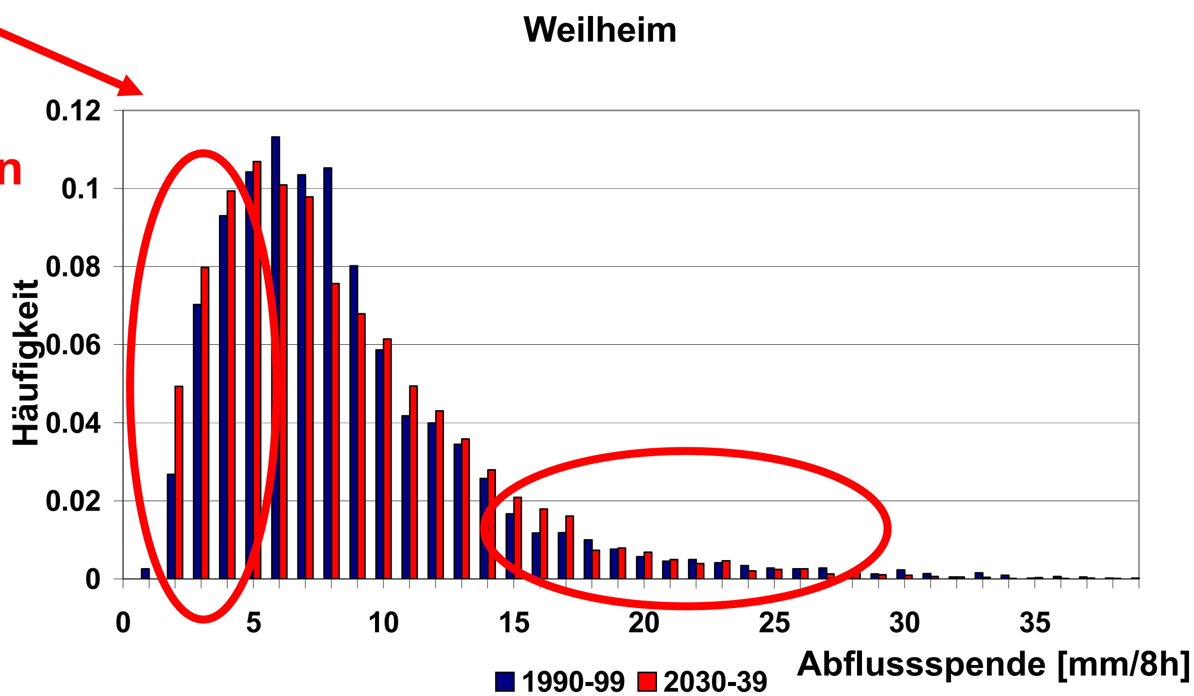
Zunahme Winter-, Verminderung der Sommerabflüsse

Klimaänderung & Wasserverfügbarkeit Ammer

Modellkaskade ECHAM4 – MM5 – WaSiM

Änderung 1990-99 vs. 2030-39





Veränderung der Häufigkeiten: Zunahme von Hochwasser & Niedrigwasser!

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Vielen Dank für die Aufmerksamkeit

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