Model based ditributed water balance monitoring of the White Volta catchment in West Africa through coupled meteorological-hydrological simulations

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[3)] **Hydrological Services Department, Accra, Ghana**

Motivation

- Simulations for the quantification of spatial and temporal changes of water balance variables requires meteorological input data

  1. dense observational network
  2. model based approach

- in catchments with weak infrastructure meteorological measurements are not or insufficient available
- Research question:

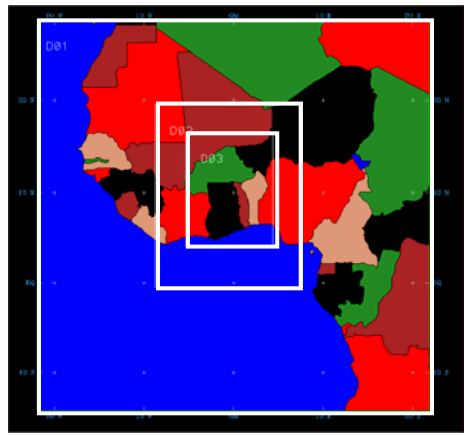
  To what extent meteorological models are able to provide the required meteorological fields?

- One-way coupled atmospheric-hydrological model system
- Kunstmann, H. et al: „Integration of atmospheric sciences and hydrology for the development of decision support systems in sustainable water management“

Atmosphere- Hydrosphere coupling

- Temperature
- Precipitation
- Wind
- Relative Humidity
- Global Radiation

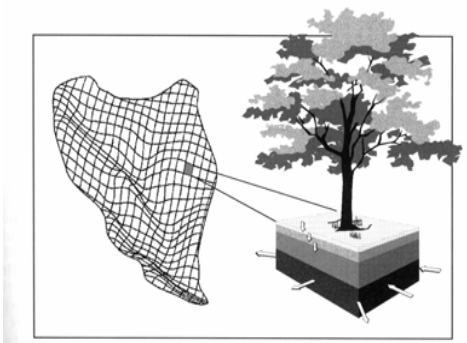
MM5
3-dim
Atmospheric model



1.0°x1.0° → 9kmx9km resolution

WaSiM
Distributed Hydrological Modell

- Orography
- Land Use
- Soil Properties
- Aquifer Properties
- Flownet Structure



1km²x1km² Resolution

Evapotranspiration **Infiltration** **Surface Runoff** **Groundwater Flow**

Motivation

- Additionally gridded information land surface properties (e.g. albedo, LAI) are difficult to obtain
- Information is taken from table depending on land use
- But satellite remote sensing (e.g. MODIS) provides worldwide spatially information on land surface properties
- Satellite derived gridded land surface data are integrated into hydrological model
- Cooperation with the Remote Sensing Group, Department of Geopgraphy, University Wuerburg: Réne Colditz & Christopher Conrad

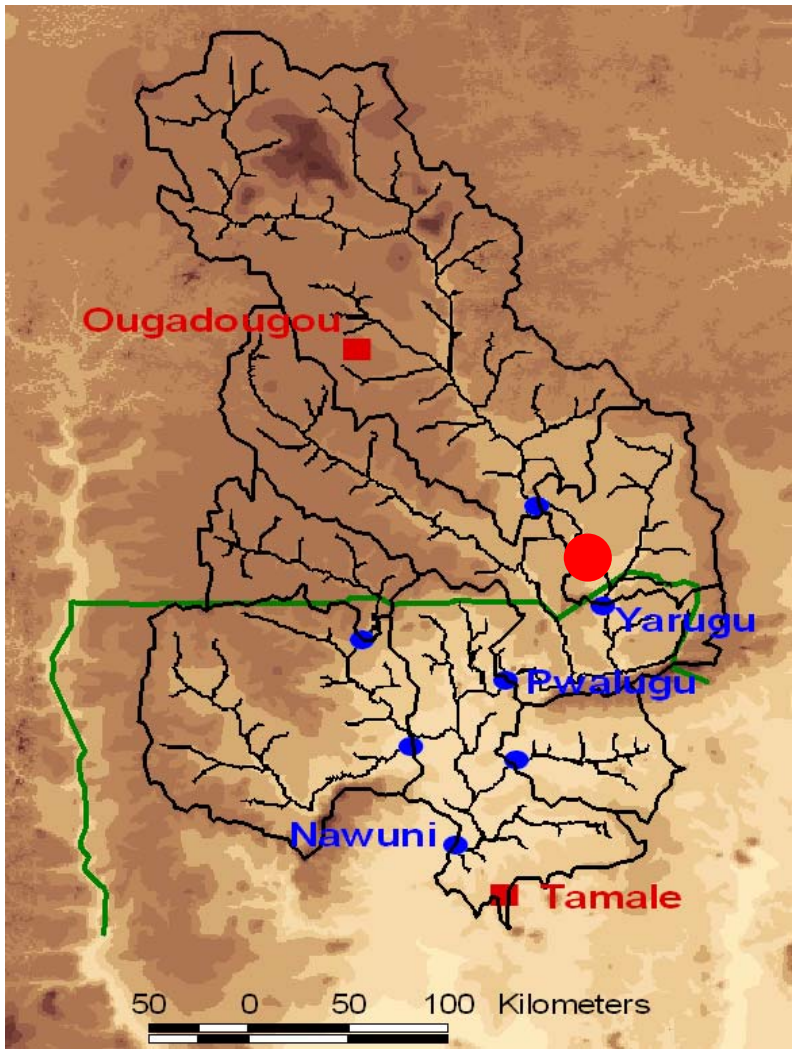
Modis Abb.

White Volta catchment / West Africa

- upstream of Lake Volta
- lat
- iarid
- : may - october
- vovember – april
- vanna (Guinea, Sudan)
- oil

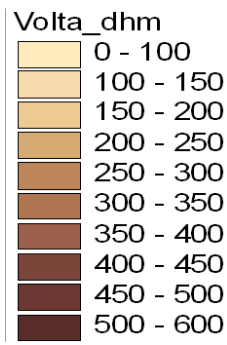
aus Encartawa Weltatlas

White Volta catchment / West Africa



Weiße Volta EZG (94044 km²):
- Modellauflösung 1x1km²
- Einteilung in 7 TEZG

Fokus liegt im Ghana-Teil:
- Projekt
- Staudamm (Bagré ●) in Burkina Faso an d. Grenze
- Verfügbarkeit der Messdaten



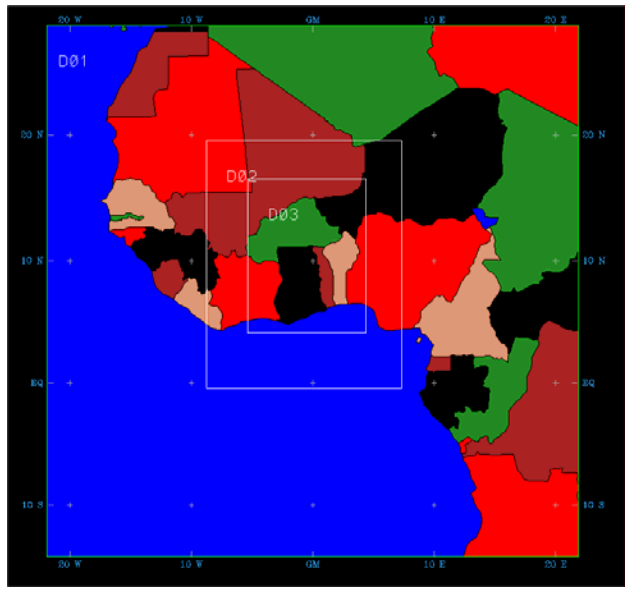
DHM 3D mit TEZG einfügen

Meteorological Model MM5

Mesoscale Meteorological Model MM5 (Penn State/NCAR)

Characteristics:

- **Non-hydrostatic dynamics**
- **Terrain following coordinates**
- **Multiple nesting capability (1-way and 2-way)**
- **Four Dimensional Data Assimilation**

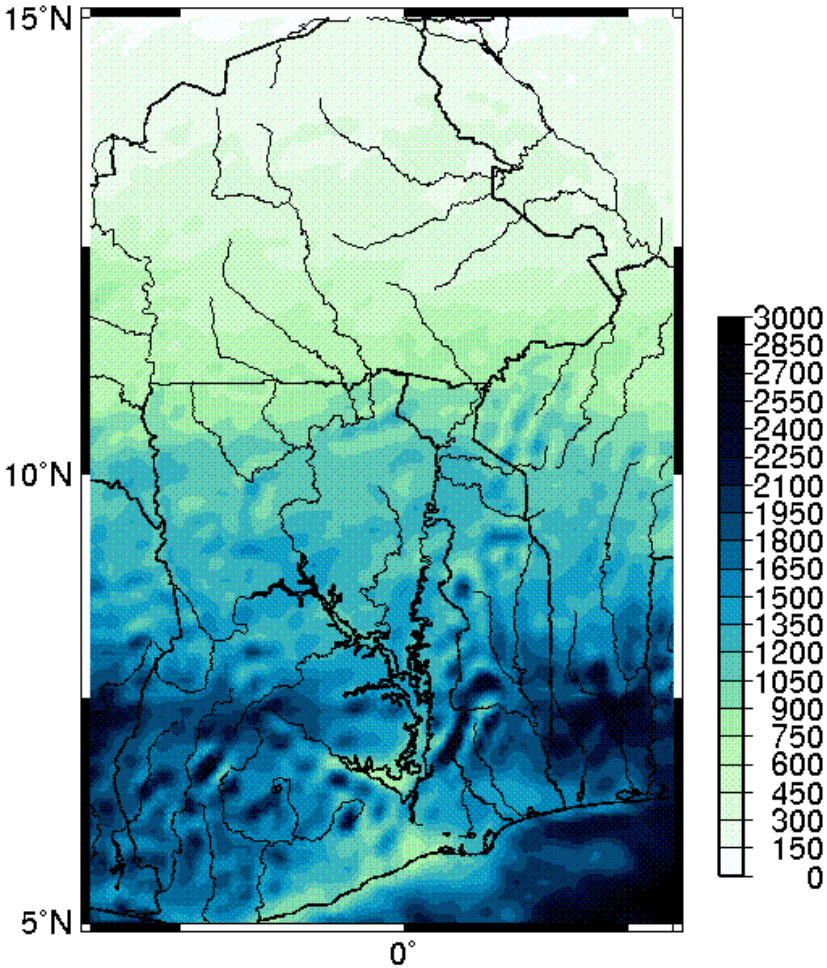


Setup:

Dynamical downscaling
Domain1: 81 x 81 km²
Domain2: 27 x 27 km²
Domain3: 9 x 9 km²
vertical resolution:
25 layers up to 30hPa
Period: 2004
AVN – (NCEP)
radiosonde- data

Ergebnisse MM5

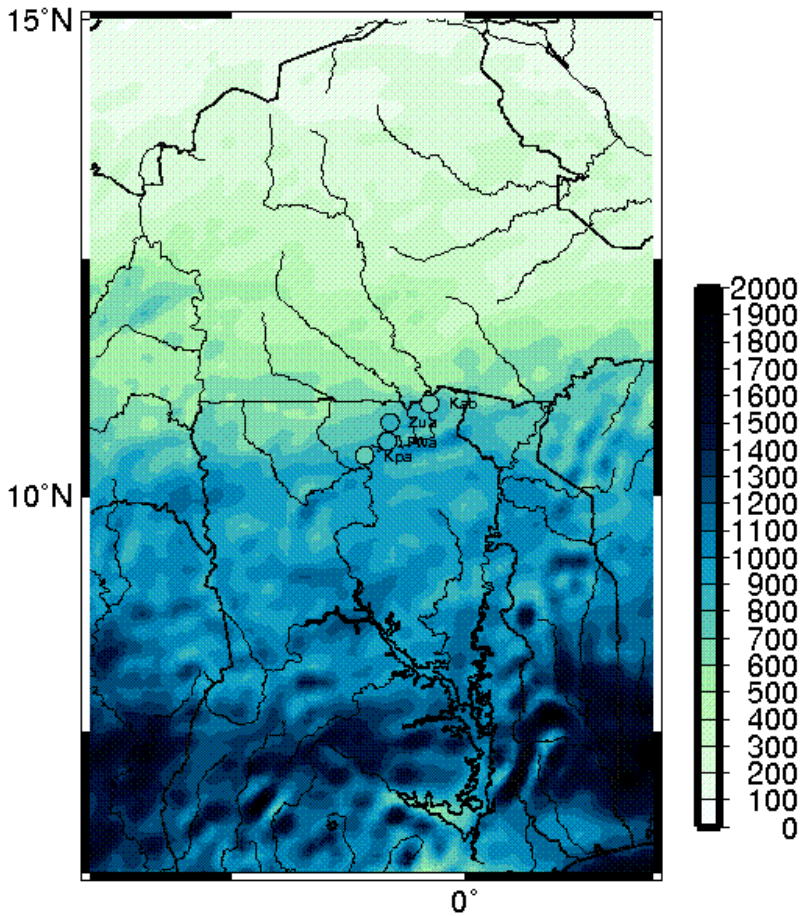
Jahresniederschlagssumme 2004 [mm]

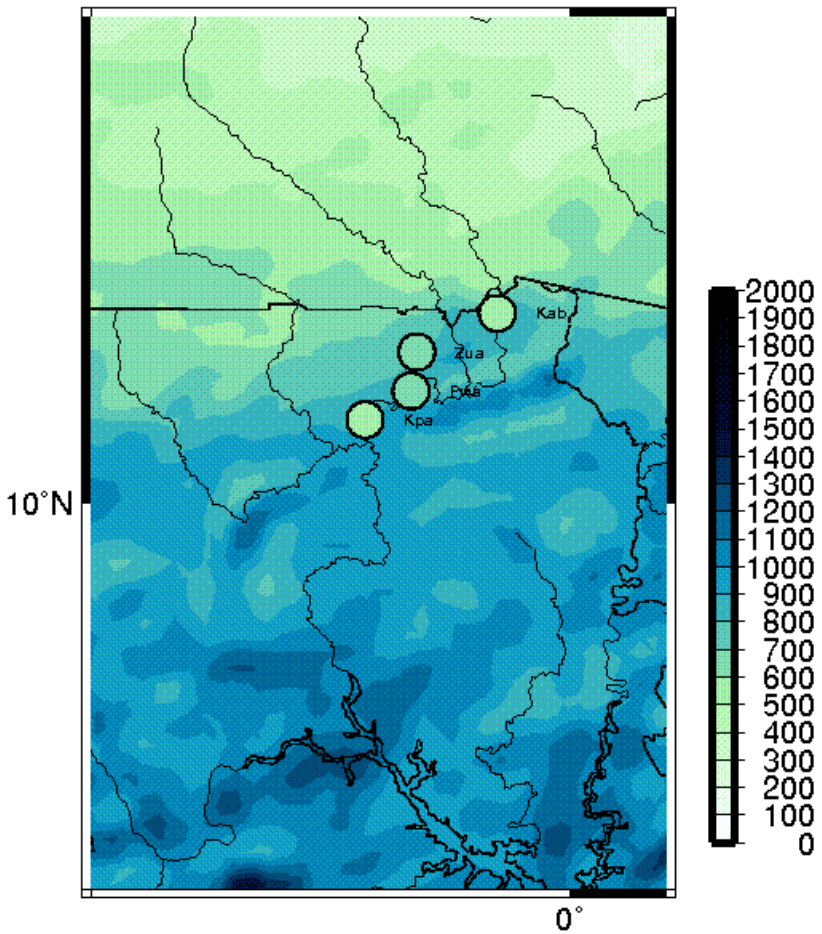


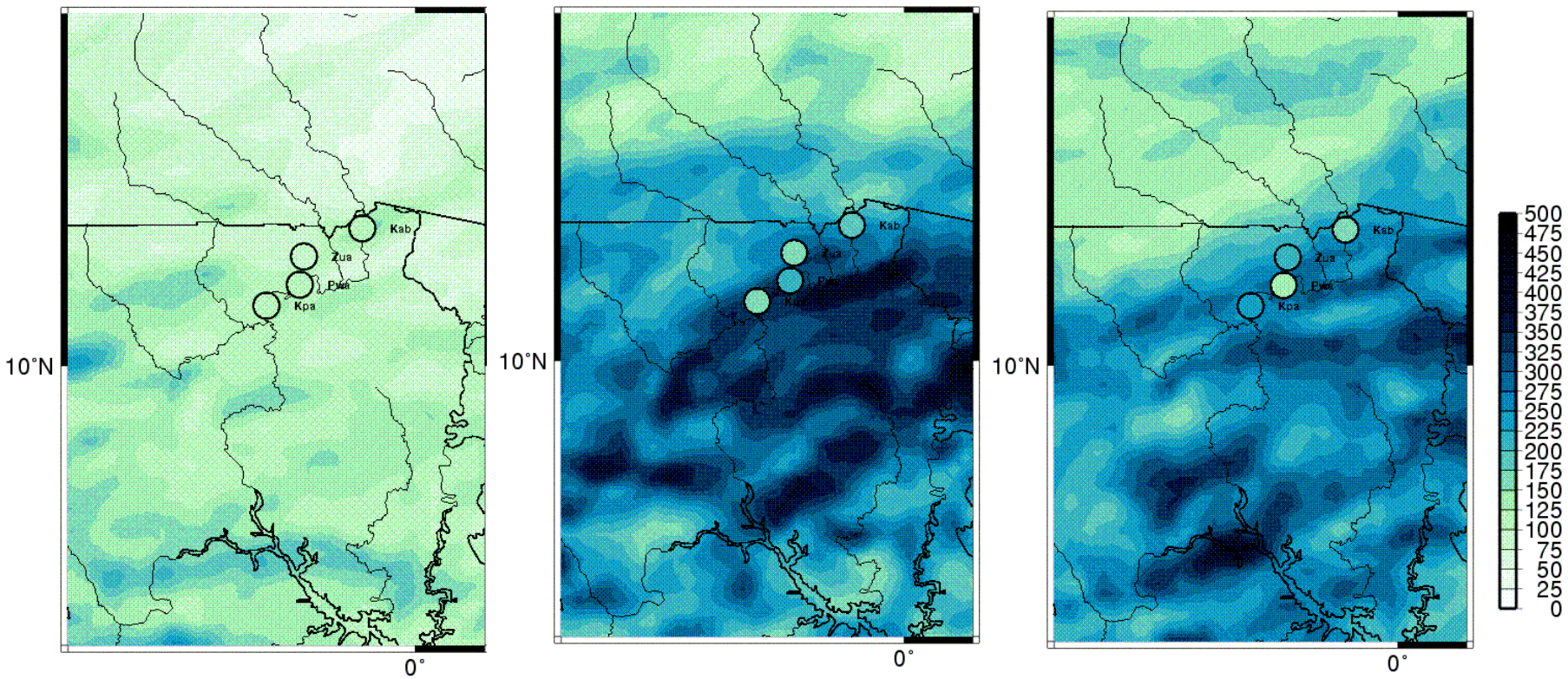
Domain3: 9x9km²

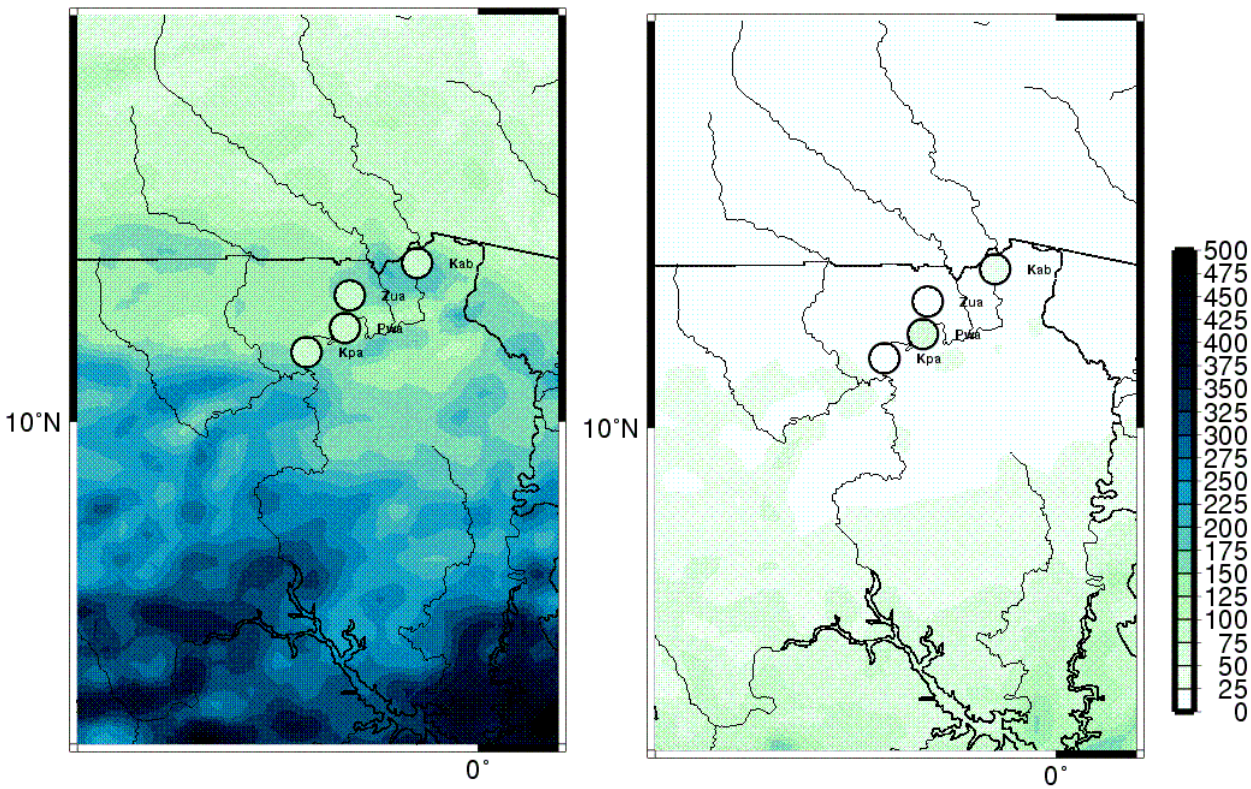
Neue Abb. mit Stationsdaten pro Monat einfügen

2004.13 entspricht jun-okt2004






10°N
0°
Kab
Zua
Pwa
Kpa
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0

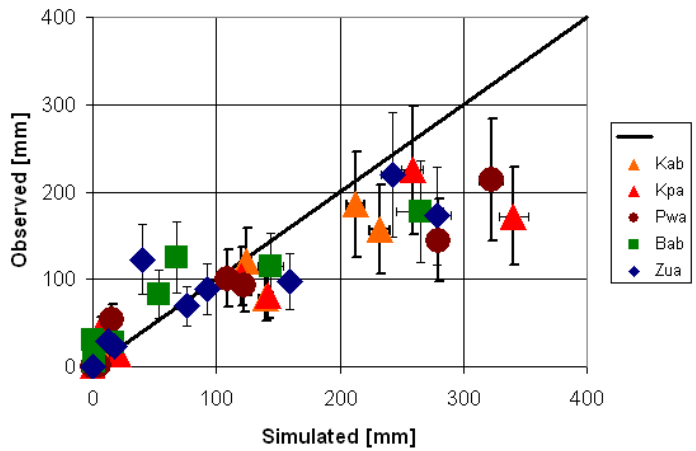

Kab
Zua
Pwa
Kpa
10°N
0°
Kab
Zua
Pwa
Kpa
10°N
0°
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0

Ergebnisse MM5: Validierung

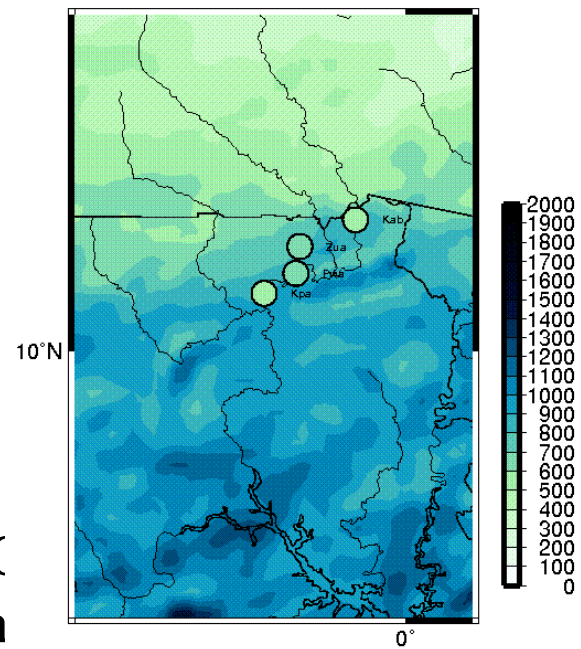
Variabilitäten:

- subgridskalige Niederschlagsvariabilität bei 9 x 9 km²: Variationskoeffizient von 0.25 – 0.4 (Friesen)
- Variationskoeffizient der 4 Nachbar- MM5- Gridpunkte

Siehe Abb davor plus neue Scatterplot



Beobachteter vs. Simulierter Monatsniederso



Überschätzung der Niederschlagssummen

20(
jun

Hydrologie Modell

Übersetzen und evtl Harald's Folie

WaSiM-ETH (Schulla)

- Wasserhaushalts- Simulationsmodell
- flächendifferenziert
- meist physikalisch basiert

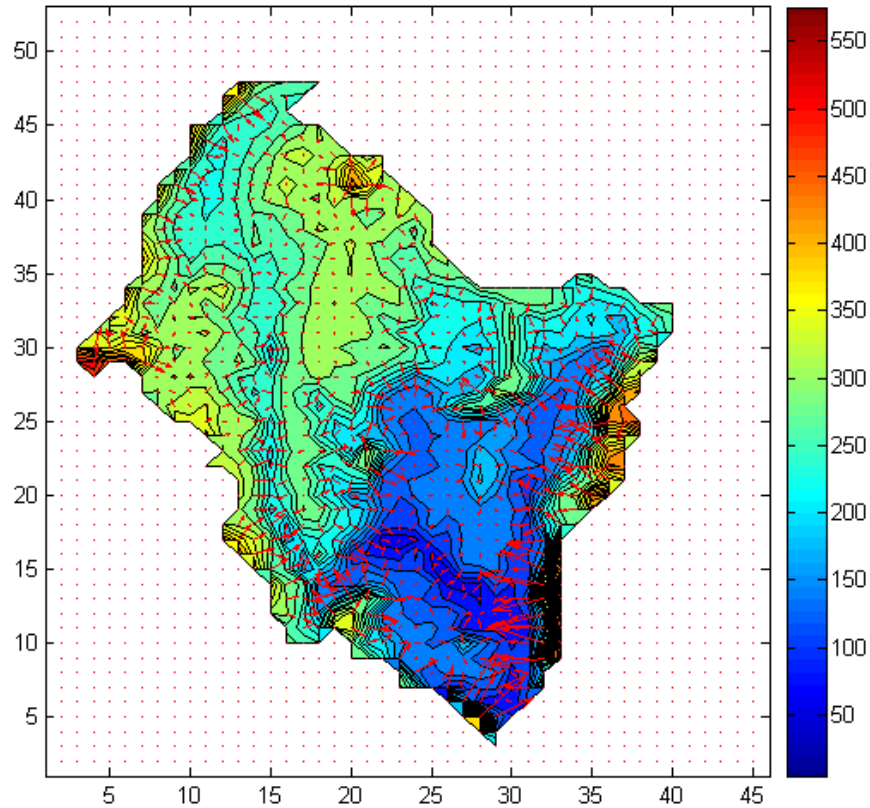
Modellstruktur:

- Interpolation meteorologischen Eingangsdaten
- ETP (Penman-Monteith)
- ETR abhängig v. Bodenfeuchte und Vegetation
- Interzeption: Überlaufspeicher
- Infiltration (Green & Ampt)
- Ungesättigte Zone (Richards)
- 2D Grundwassermodell
- Routing: Kinematische Welle

Distributed Hydrological Model WaSiM-ETH

Physically based algorithms for most process descriptions

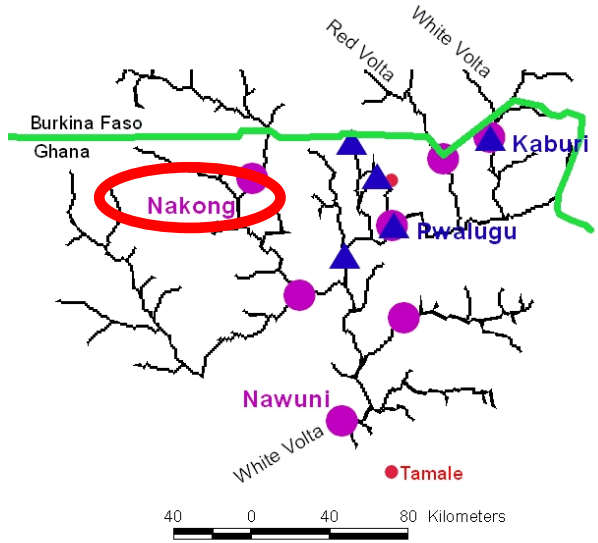
- Infiltration (Green & Ampt, 1911)
- Flow through unsaturated zone (Richards, 1931)
- Suction head & hydraulic conductivity (van Genuchten, 1976)
- Evapotranspiration: soil and vegetation specific (Monteith, 1975; Brutsaert, 1982)
- Translation & retention of infiltration excess to sub basin outlet (flow time zones)
- Discharge routing: cinematic wave
- 2-dim groundwater model dynamically coupled to unsaturated zone



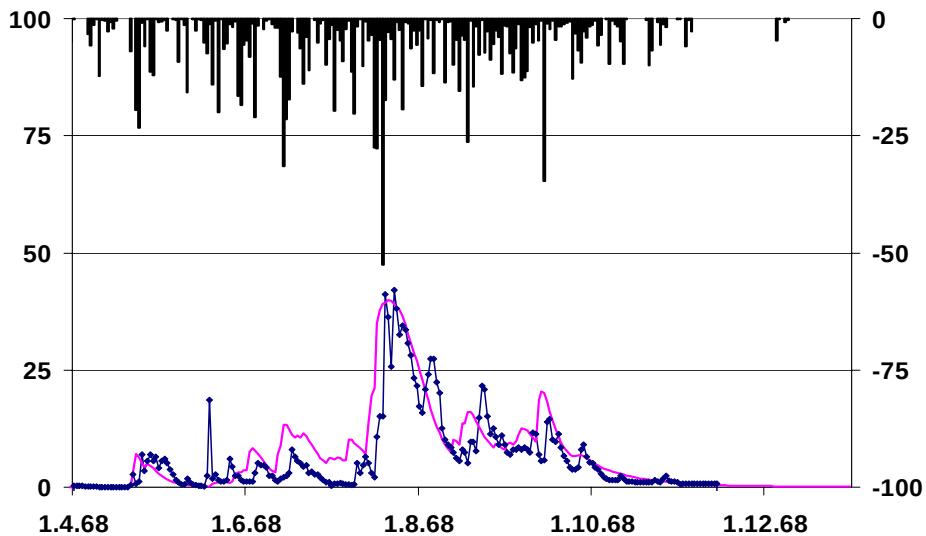
Kalibrierung mit Stationsdaten

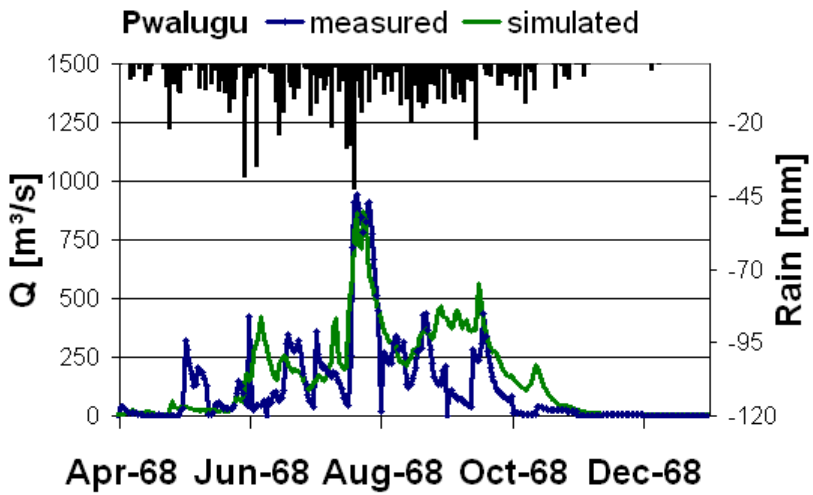
Kalibrierung v. WaSiM-ETH für 1968:

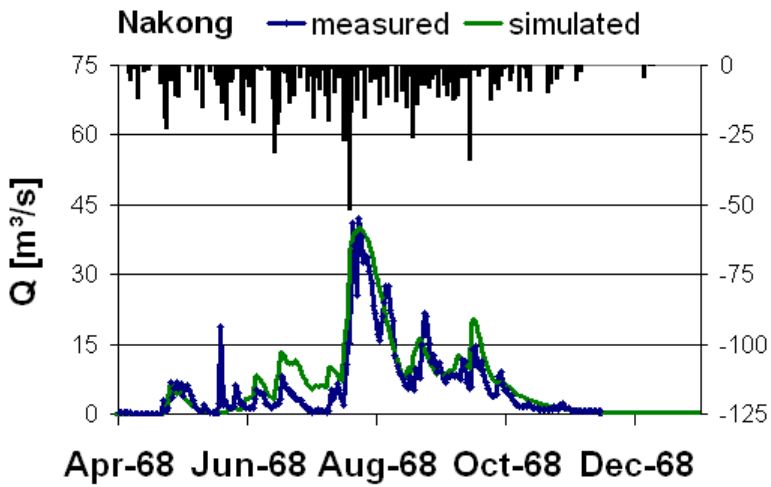
- Datenverfügbarkeit
- anthropogenen Einflüsse (Dämme, Bewässerung) gering
- WaSiM anpassen an Bedingungen vor Ort
- Kalibrierung der sensitiven Parameter

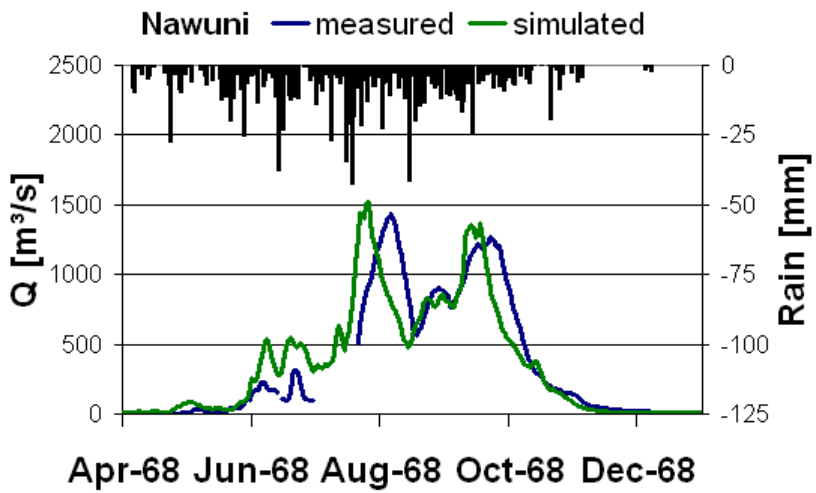


Oberflächenabfluss [m³/s]
Nakong Sissili
Pink: simuliert; Blau:gemessen;
Schwarz: Niederschlag (neg.)

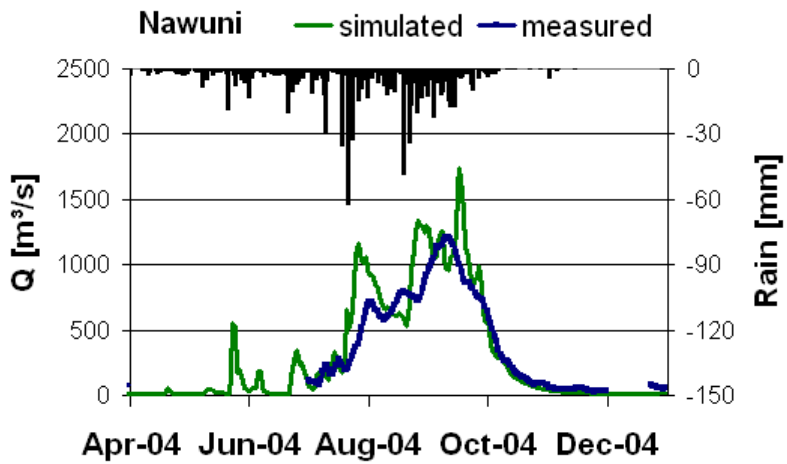


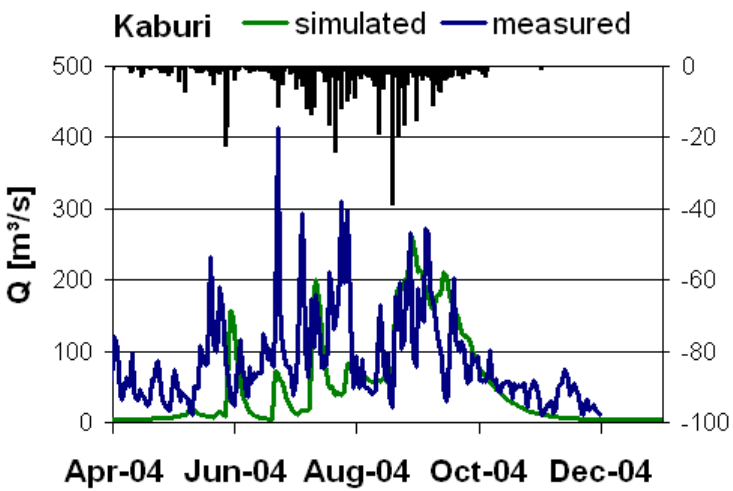

Pwalugu
measured
simulated
1500
1250
1000
750
500
250
0
Q [m³/s]
-20
-45
-70
-95
-120
Rain [mm]
Apr-68
Jun-68
Aug-68
Oct-68
Dec-68

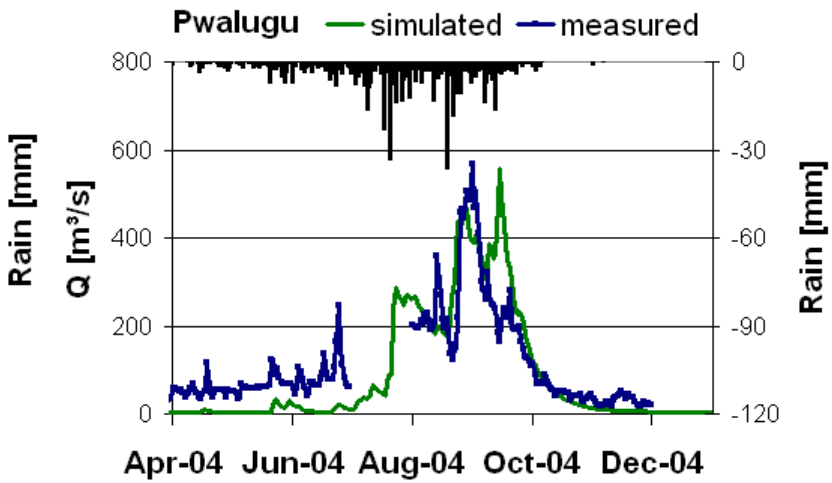

Nakong
measured
simulated
75
60
45
30
15
0
Q [m³/s]
0
-25
-50
-75
-100
-125
Rain [mm]
Apr-68
Jun-68
Aug-68
Oct-68
Dec-68


Nawuni
measured
simulated
2500
2000
1500
1000
500
0
Q [m³/s]
0
-25
-50
-75
-100
-125
Rain [mm]
Apr-68
Jun-68
Aug-68
Oct-68
Dec-68

Kopplungserg. 2004
04-12/2004



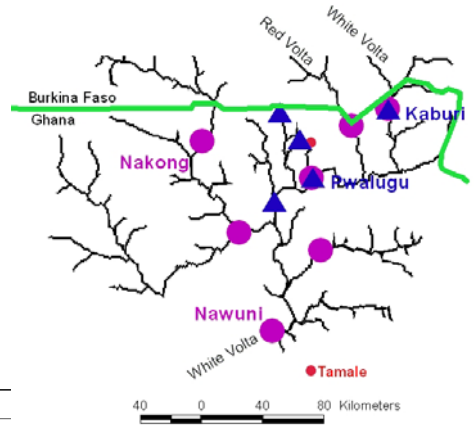




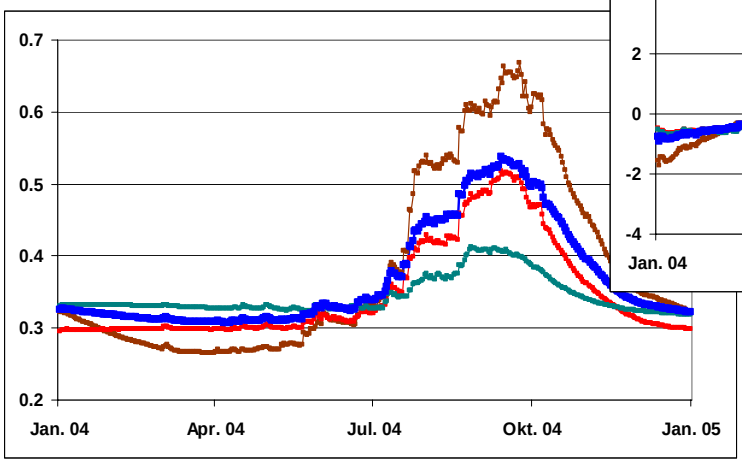
Gekoppelte Simulationen Ergebnisse

Zusätzliche Informationen über relevante Wasserhaushaltsgrößen als

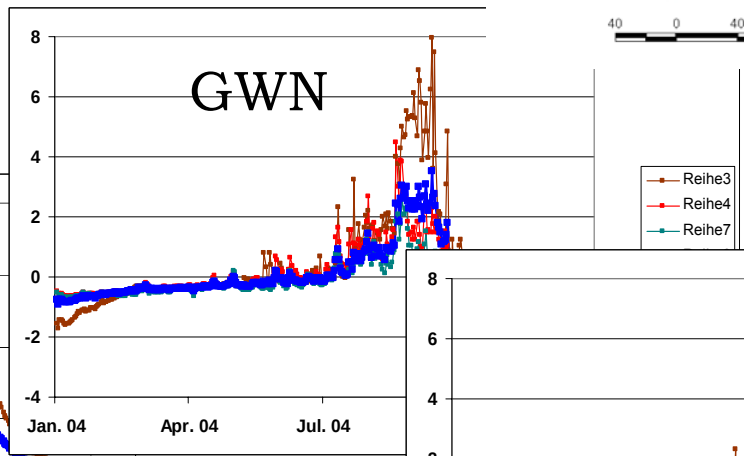
- Zeitreihen für TEZG und Gesamt;

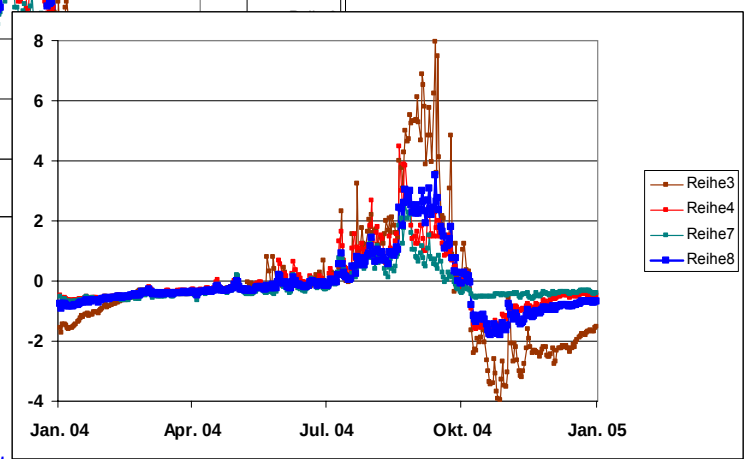


Rel. Bodenfeuchte



GWN





Legende: Yarugu Pwalugu Nawuni Mittelwert

Assimilation der abgeleiteten Satellitendaten in WaSiM

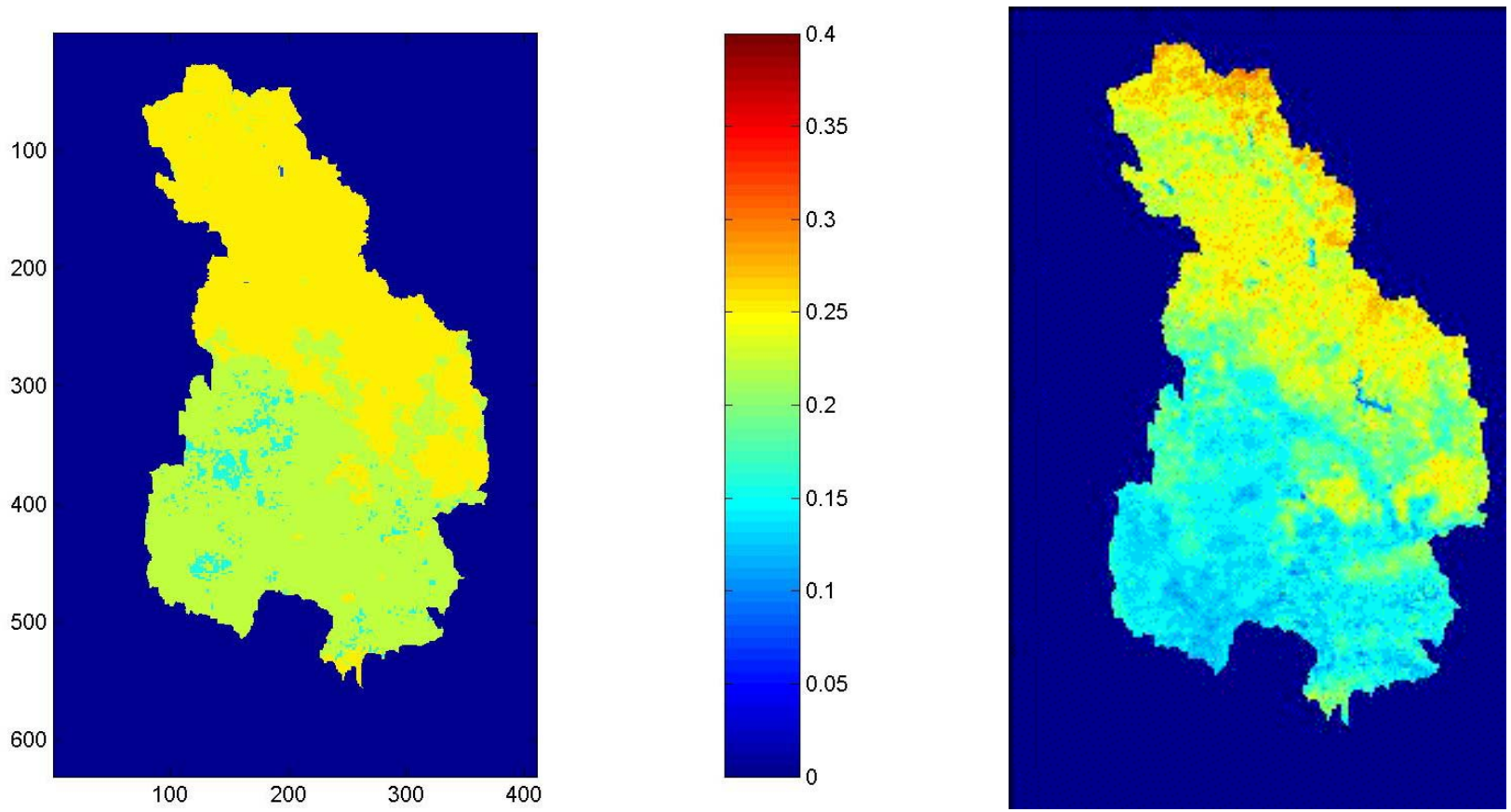
- MODIS – Produkte

- Daten vom DLR:
  - Albedo
  - LAI
  - LST
  - NDVI
  - Emissivität

  für 1 Jahr: 2002

Modis composites movies: Albedo

- WaSiM: Albedo konstant und abh. von LU (linke Abb.)
- MODIS: Albedo als16 Tage Composites für 2002 (rechte Abb.)



Modis composites movies: Albedo

- WaSiM: Albedo konstant und abh. von LU (linke Abb.)
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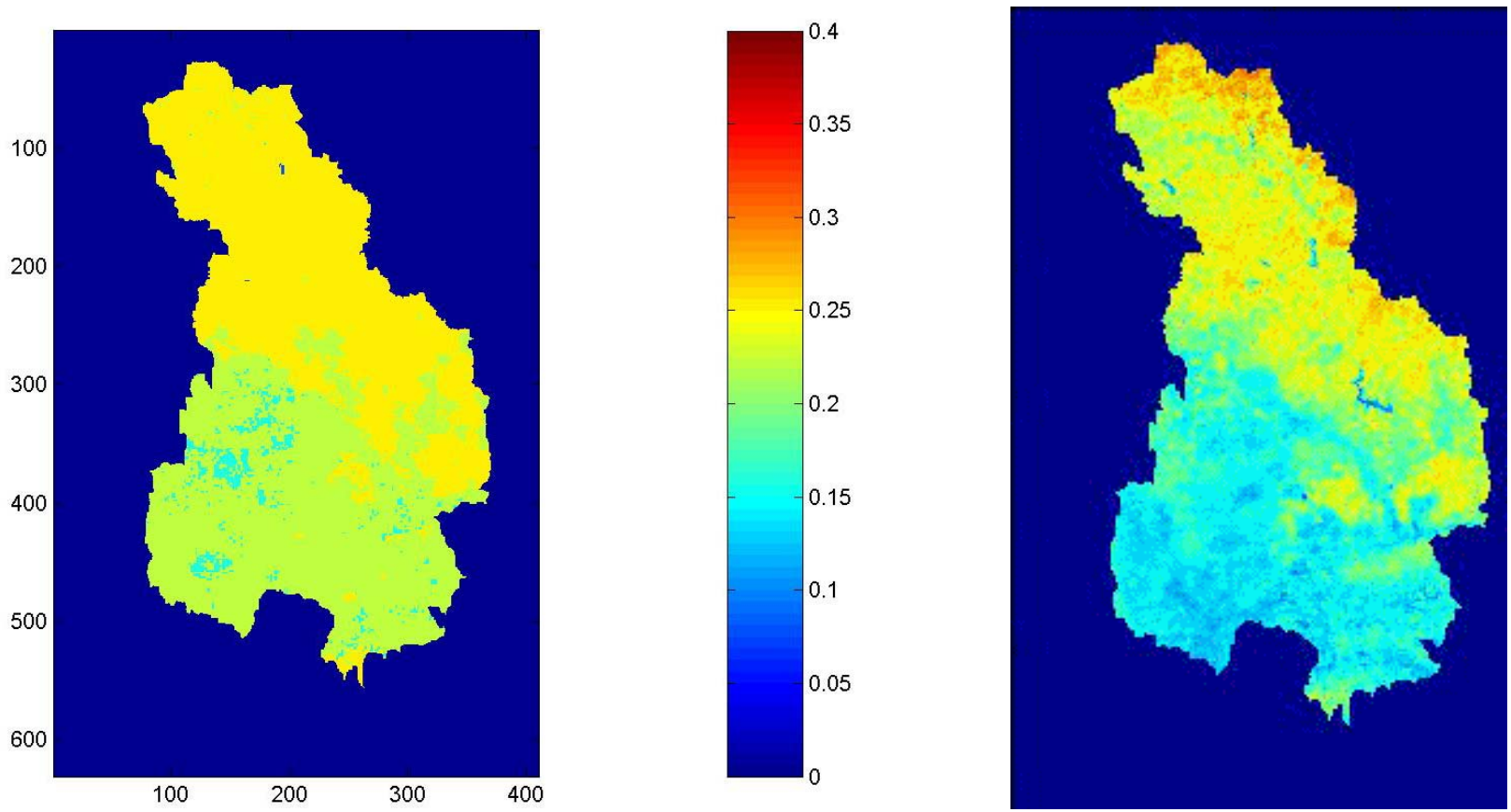
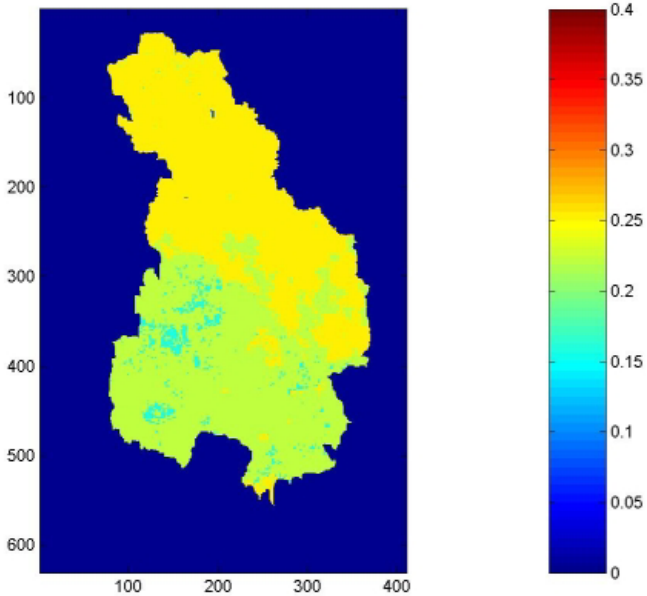
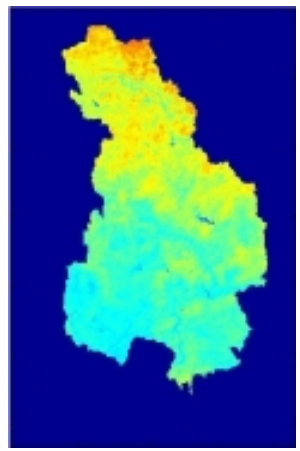
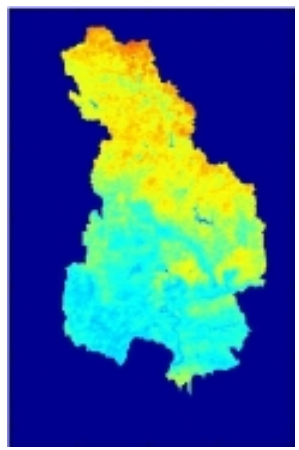
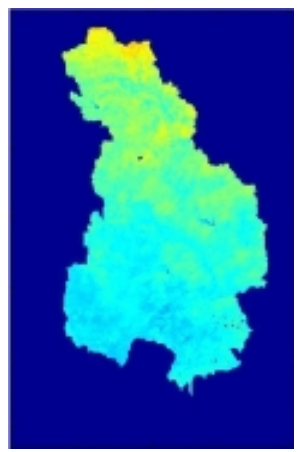


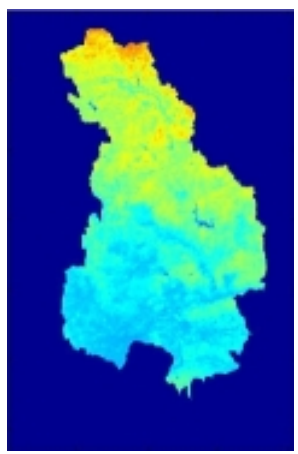
Quaterly albedo grids derived from modis in wasim



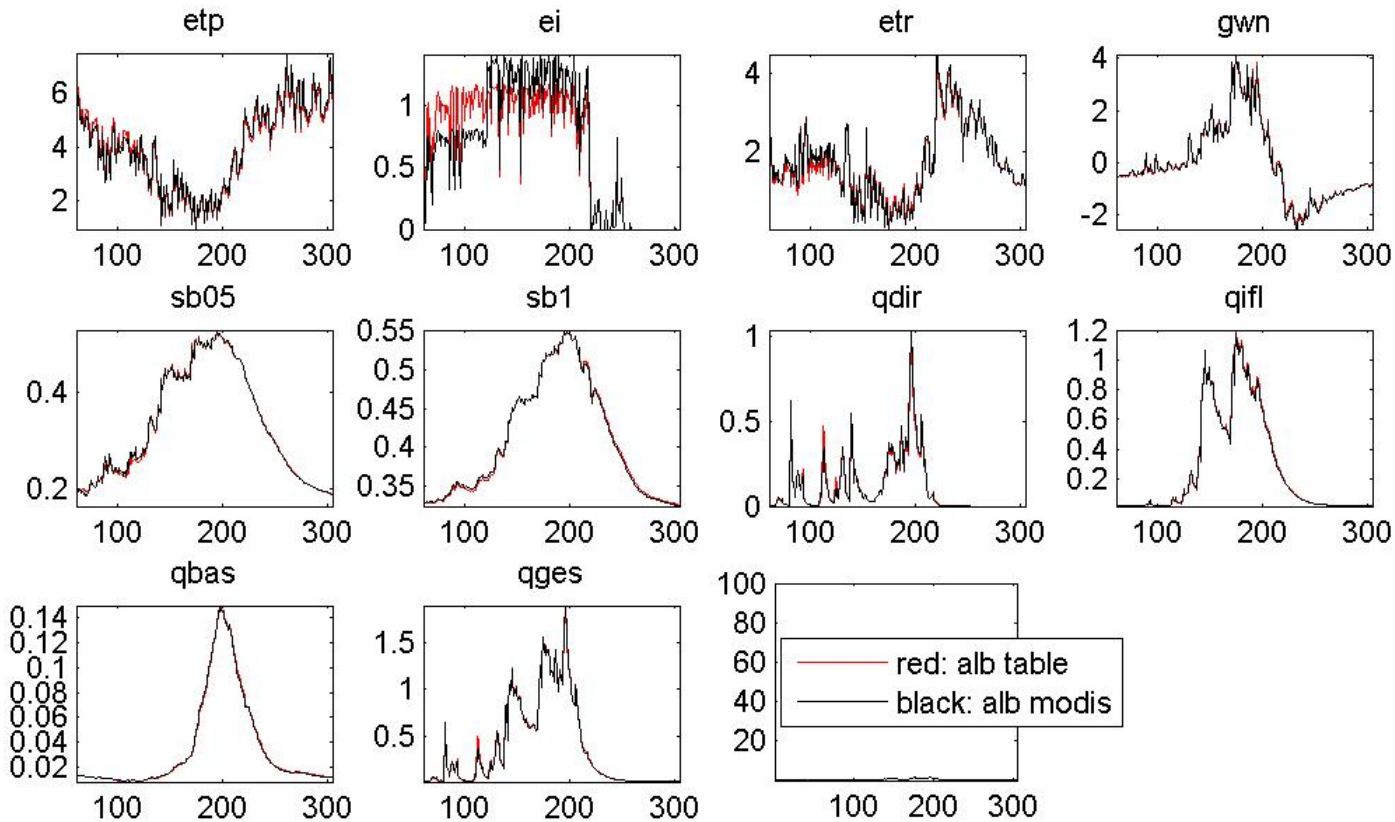




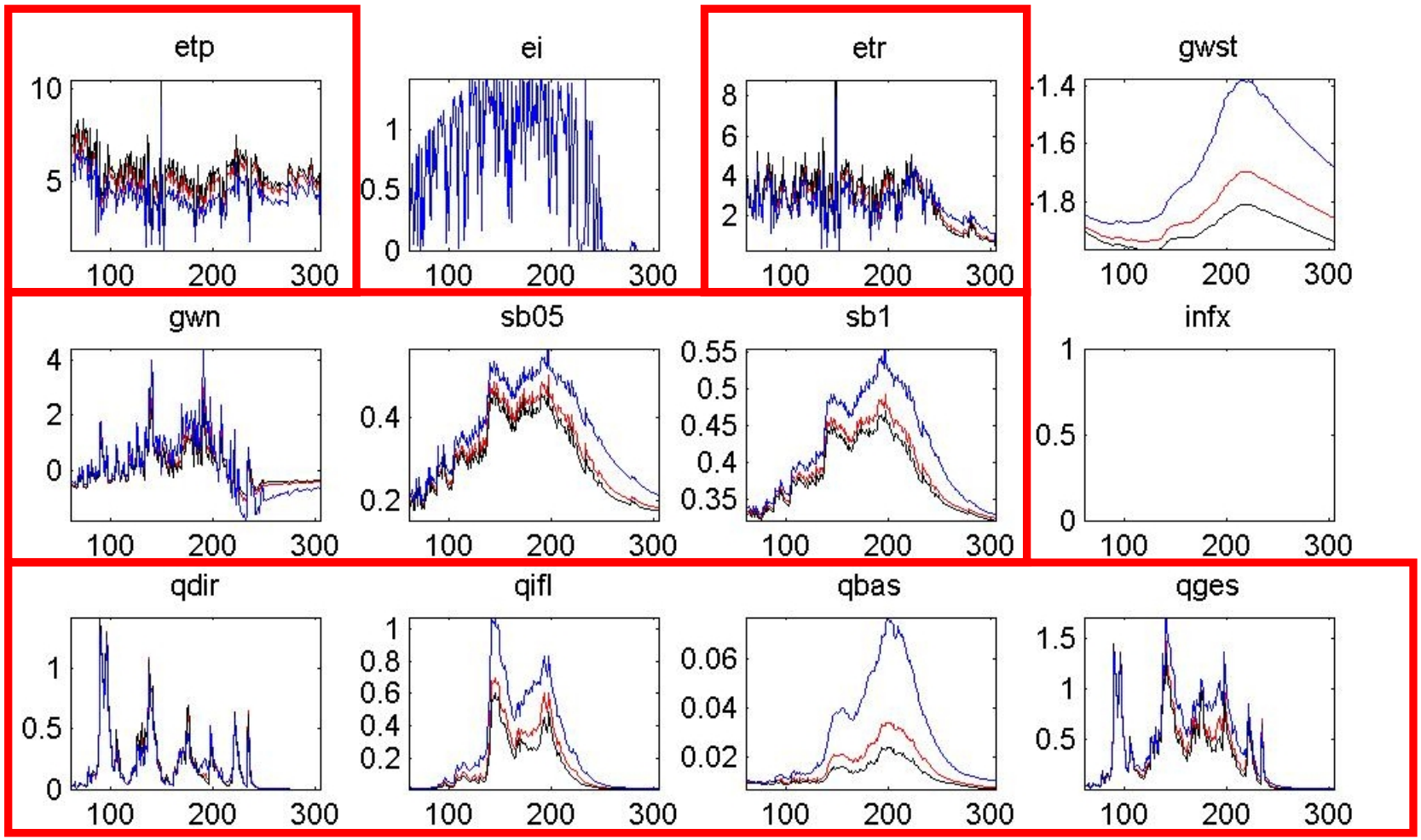




Modis Alb comparison of Wasim output



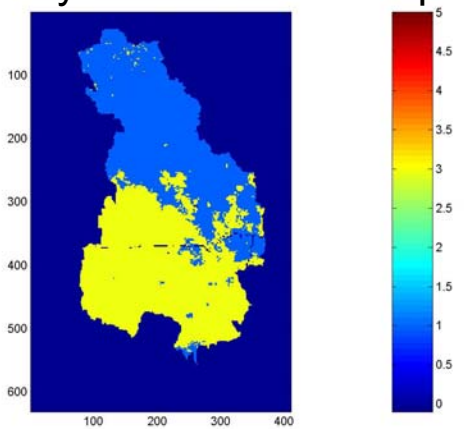
Sensitivitätsstudie WaSiM: Albedo



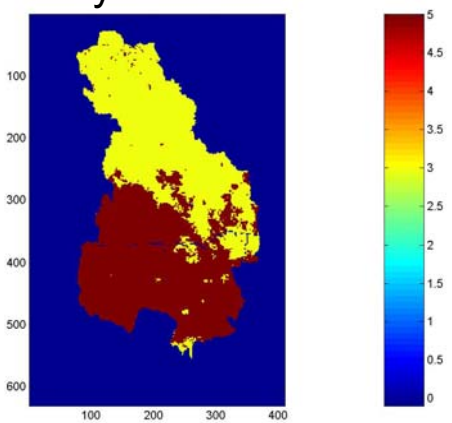
Legende: alb*0.5 alb*1.0 alb*2.0; WaSiM Setup: Stationsdaten 1968, v6.4.2

LAI from tables

dry season: Nov - Apr

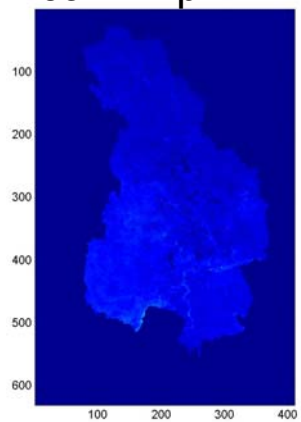


rainy season: Mai - Oct

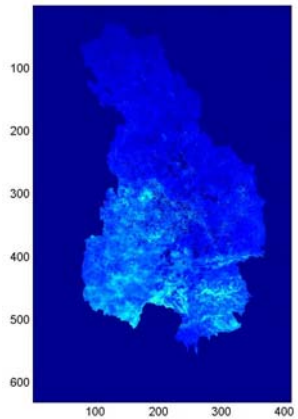


LAI derived from MODIS for 2002

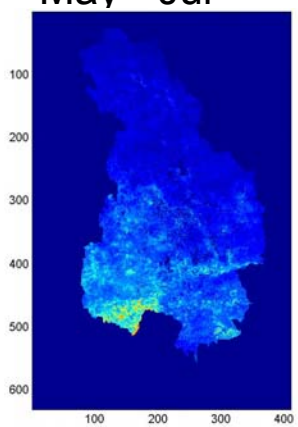
Jan - Apr



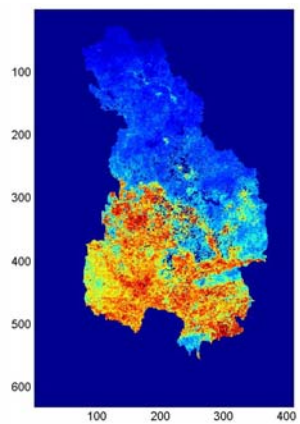
Nov - Dec

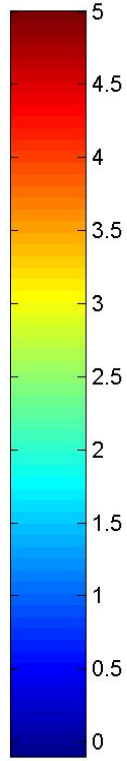


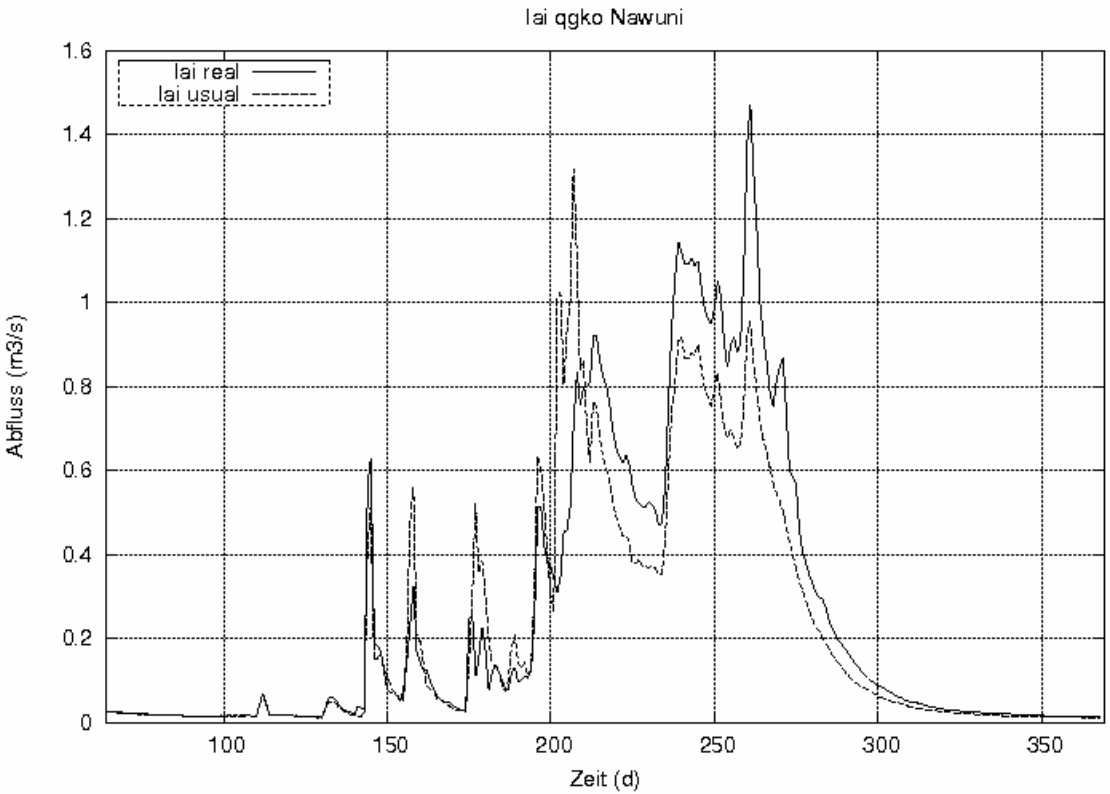
May - Jul



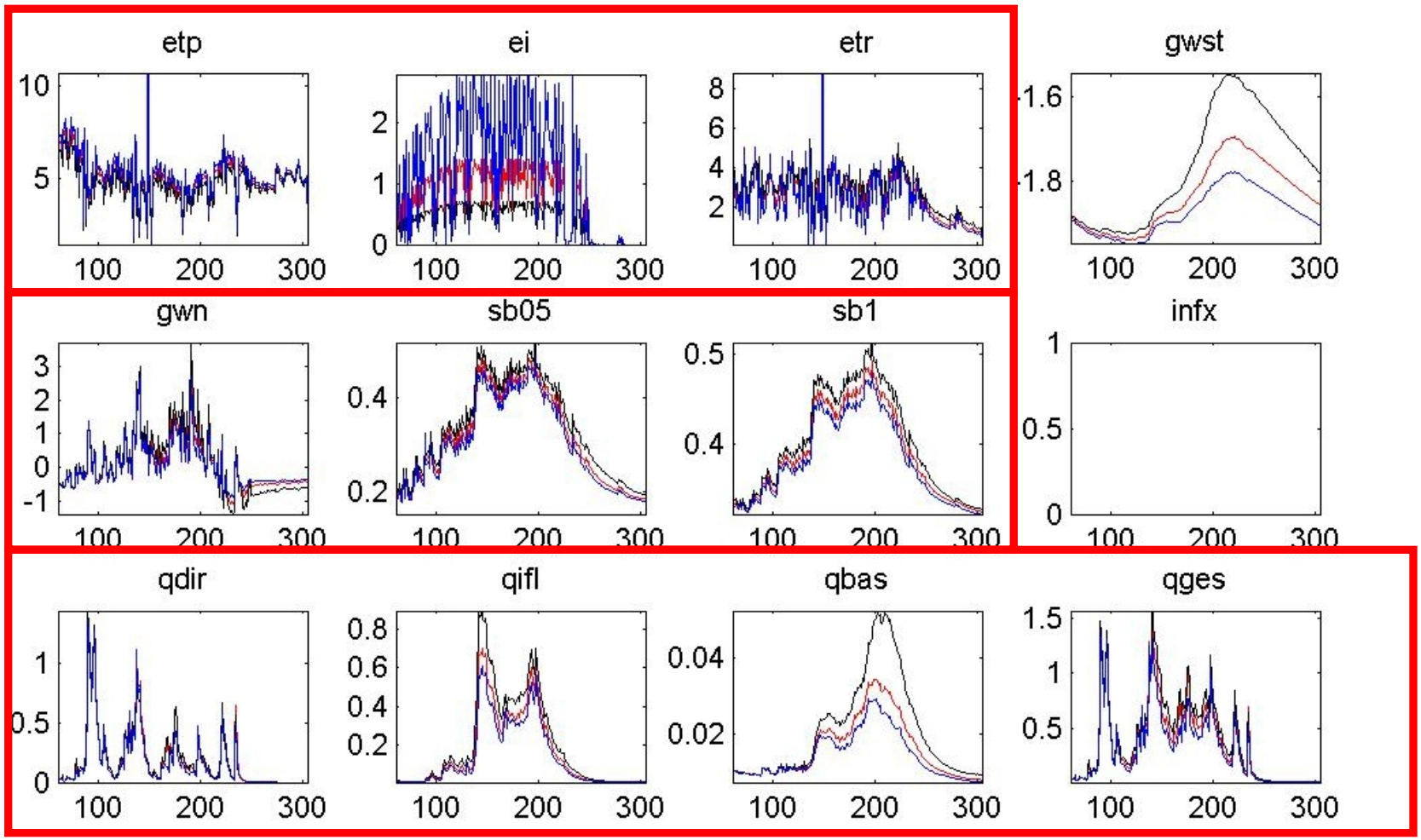
Jul - Oct






lai qgko Nawuni
lai real
lai usual
Abfluss (m3/s)
Zeit (d)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
100
150
200
250
300
350

Sensitivitätsstudie WaSiM: LAI



Legende: lai*0.5 lai*1.0 lai*2.0; WaSiM Setup: Stationsdaten 1968, v6.4.2

Summary

• Motivation: Methode zur Wasserhaushaltssimulation in infrastrukturschwachen Regionen

• gekoppelte met. – hydr. Simulationen (mit Simulationsergebnissen aus regionalen Modell für met. Eingangsdaten statt Stationsdaten)

• trotz Bias Niederschlägen, Abflüsse zufriedenstellend

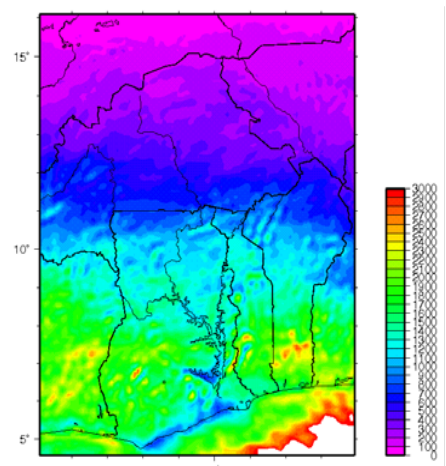
• Problem: Validierung primär über Abfluss

• Möglichkeiten:
  - operationelles hindcasting Atmosphäre & Wasserhaushalt
  - zeitnahe Erfassung Wasserhaushaltsgrößen
  - kann als Grundlage für Entscheidungen dienen


Thank you for
your attention !!

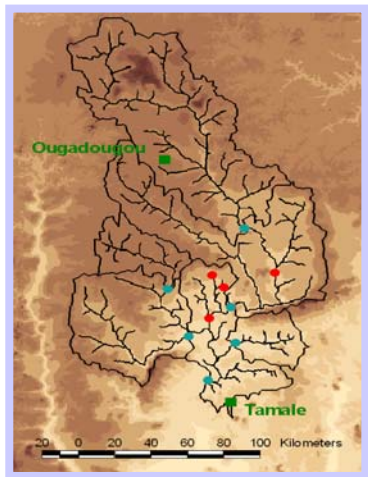
Prinzip: gekoppeltes System

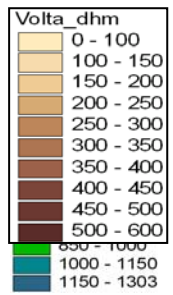
MM5



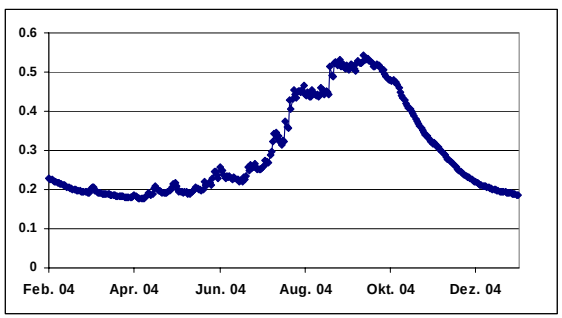
Modellbasiertes Monitoring terrestrischer Wasserhaushalt

WaSiM

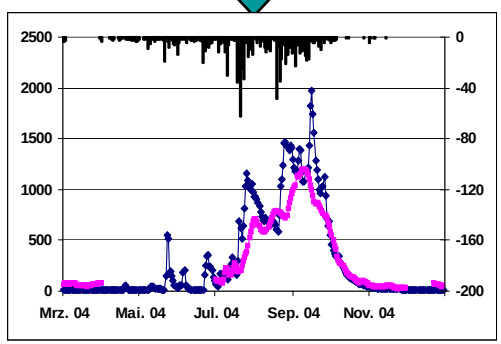




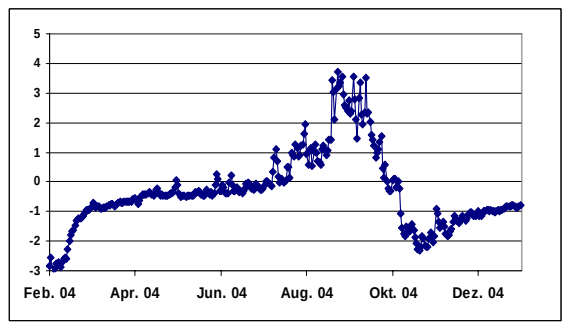
Reale ET [mm/a]



Relative Bodenfeuchte



Oberflächenabfluss [m³/s]

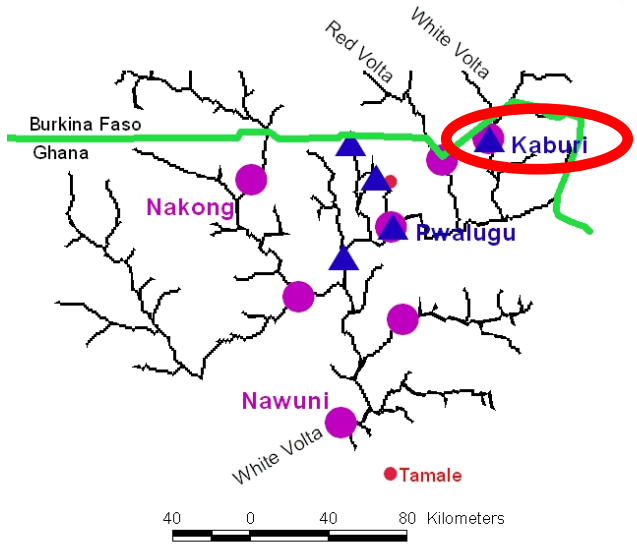


Grundwasserneubildung [mm]

Gebietsbeschreibung

Aufbau eines dichteren Messnetzes im Zusammenarbeit mit Hydrological Service Ghana

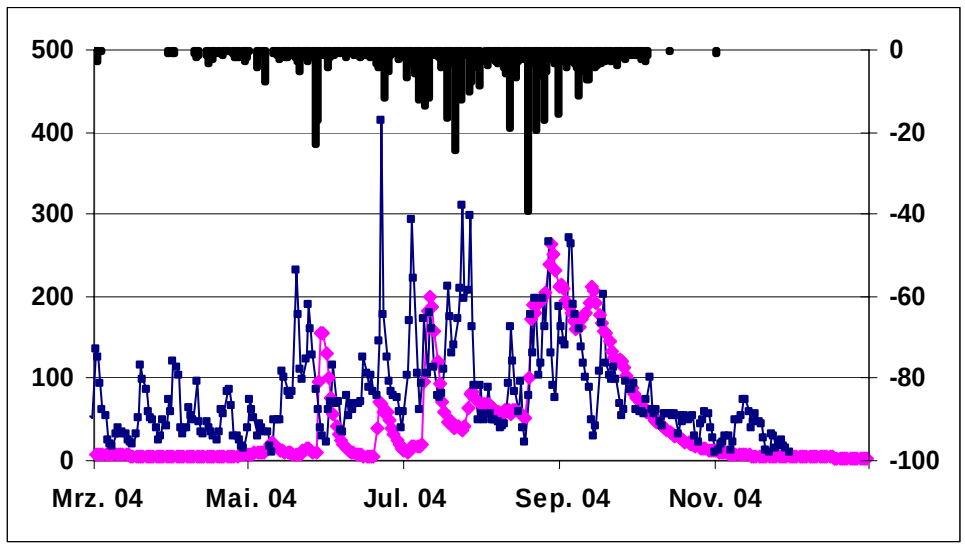
Vergleich Simulations- Ergebnisse

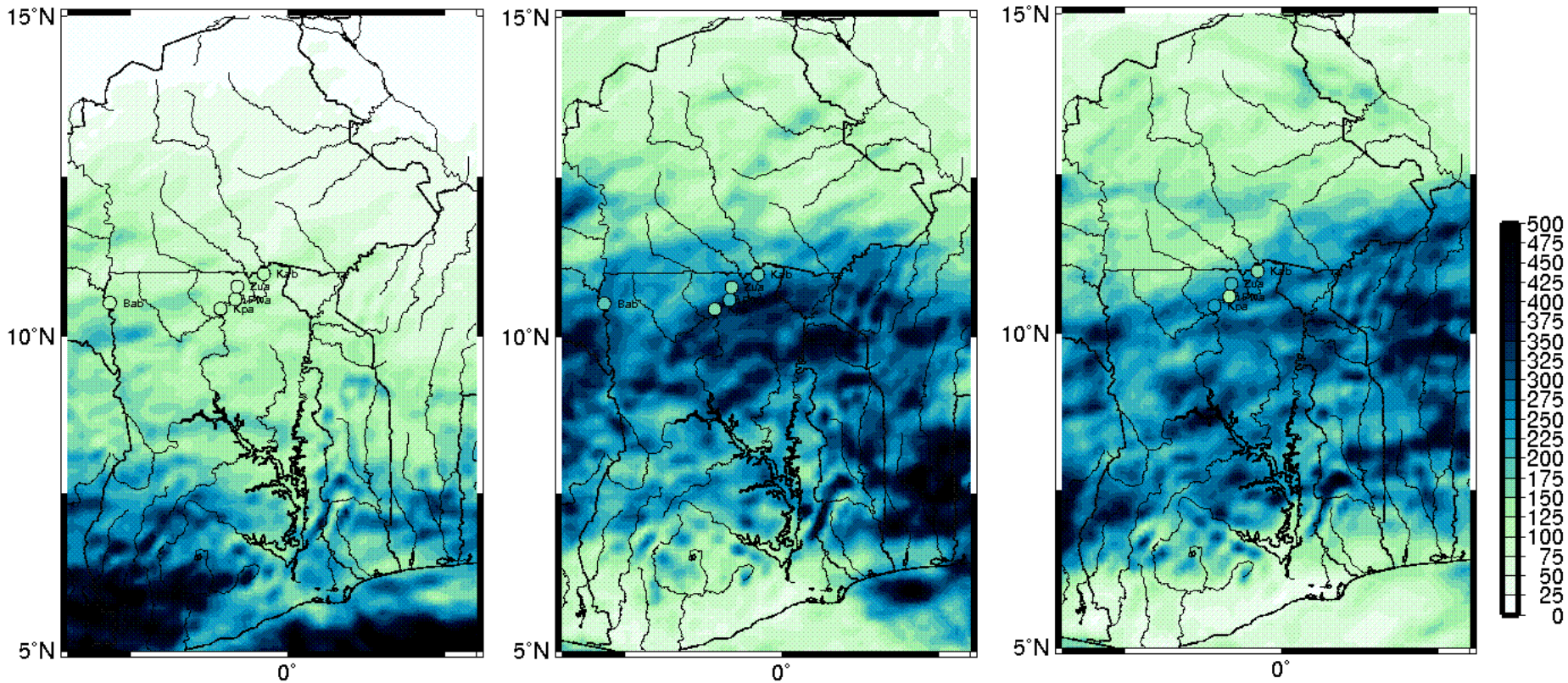


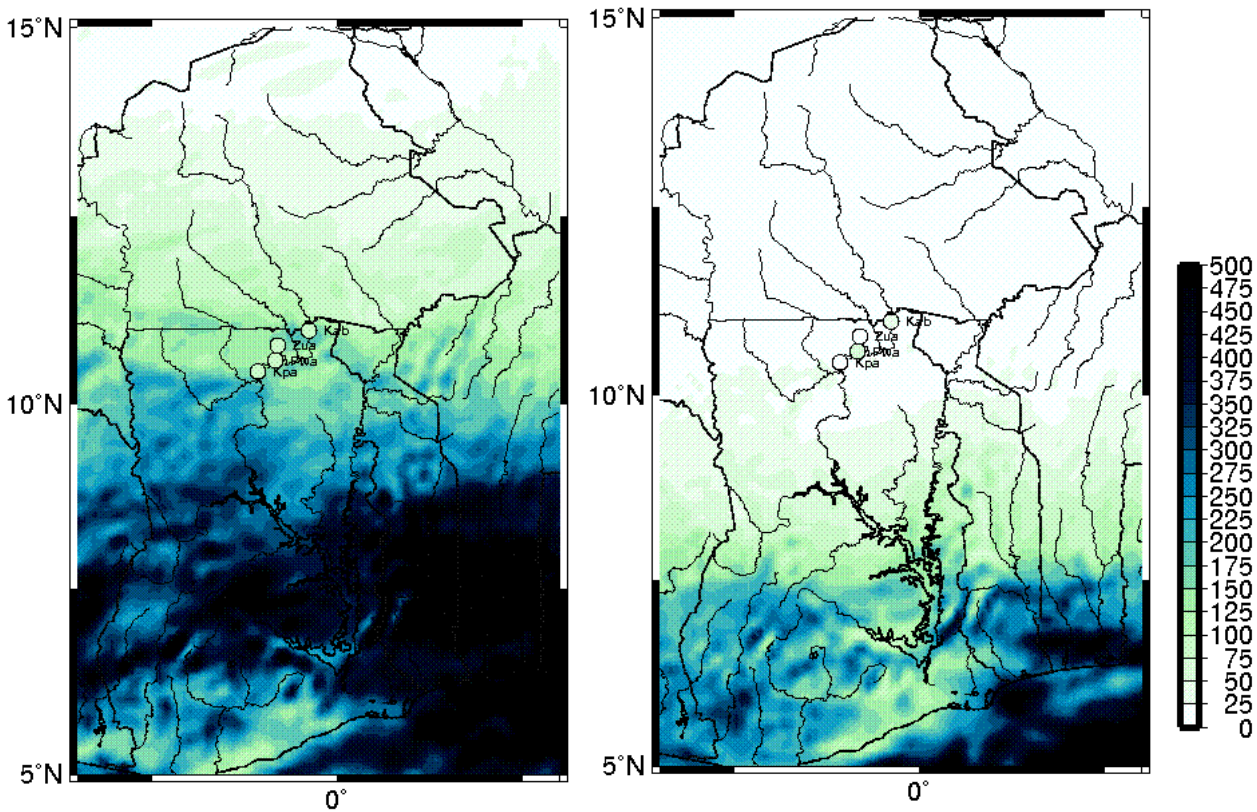
Oberflächenabfluss [m³/s]
Kaburi White Volta
Pink: simuliert; Blau:gemessen;
Schwarz: Niederschlag (neg.)

• Zufluss der Weißen Volta an der Grenze, abhängig von Auslass Staudamm

Gekoppelt: 2004




15°N
10°N
5°N
0°
Bab
Kab
Zua
Kpa
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0


15°N
10°N
5°N
0°
Kab
Zua
Lpma
Kpa
15°N
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5°N
0°
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Lpma
Kpa
500
475
450
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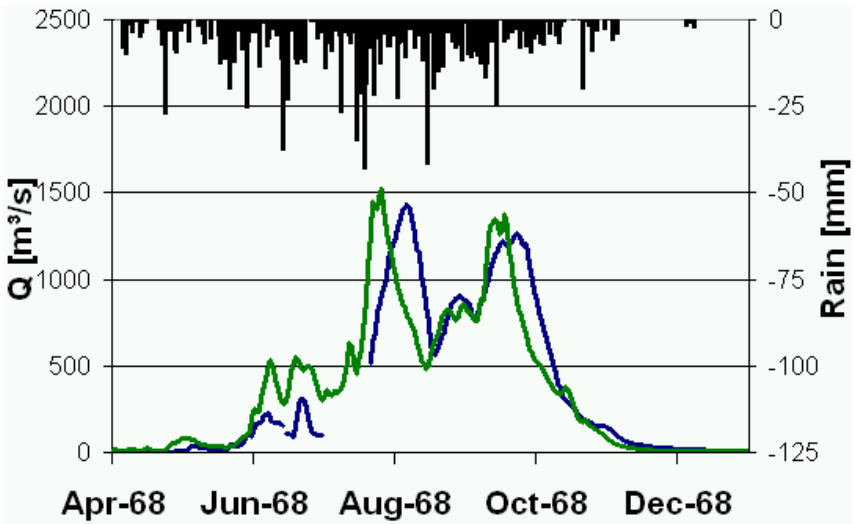
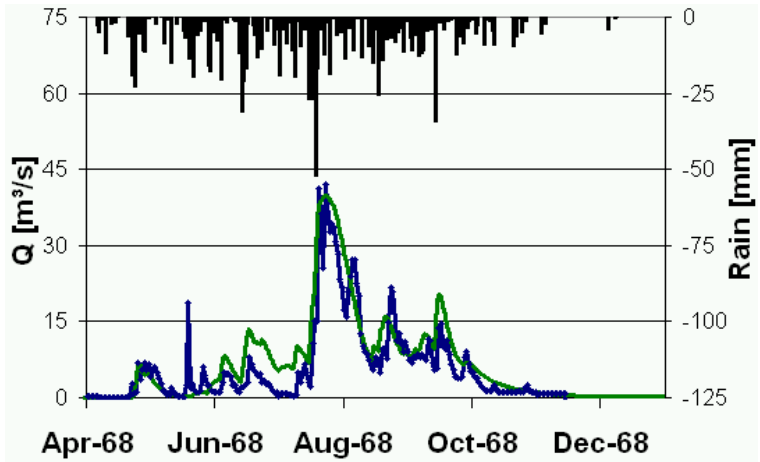
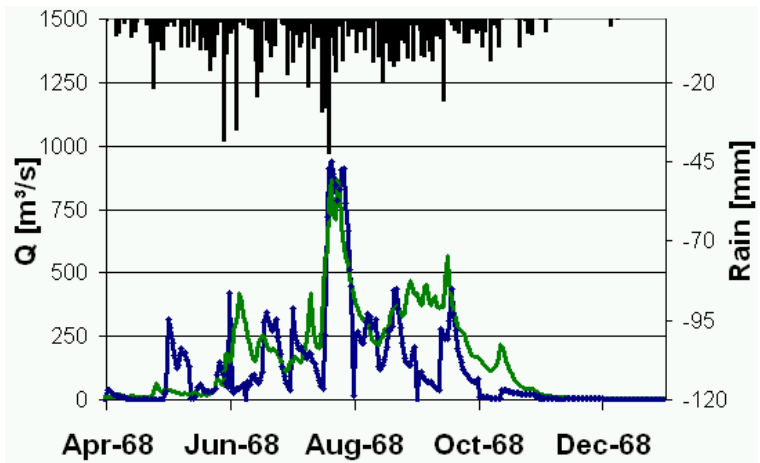
Kalibrierungserg. 68







Kopplungserg. 2004
04-12/2004