Water balance simulations in a poorly gauged basin using different meteorological and land surface data sources

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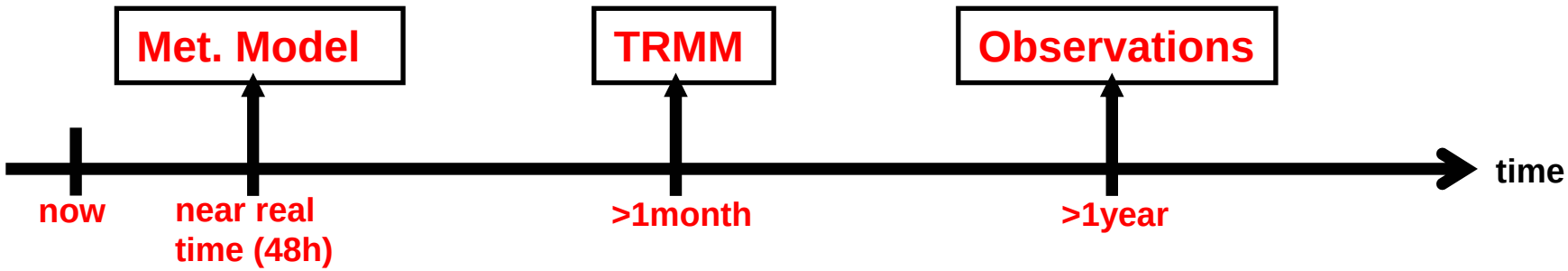
Motivation

- **Sustainable water management strategies require hydrological modeling** to quantify the spatial and temporal changes of water balance
- What are the current natural water stocks and -fluxes in the catchment?
  Near-real time distributed estimation of natural water balance
  → support irrigation, water supply, hydro power strategies

- Hydrological models require meteorological input data
- Problem in poorly gauged basins:
  Meteorological observations are not or insufficient available **(+ DELAY)**

- Used available data sources in this study:



Model Based Water Balance System

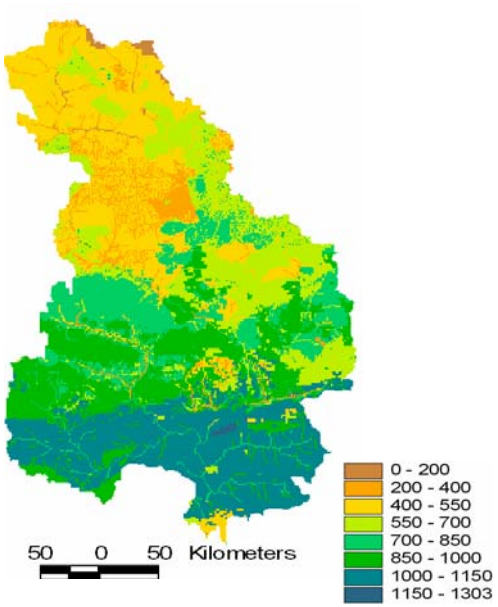
Meteorological Input

1) near real time: met. model
2) 1 month delay: TRMM
3) 1a delay: observations

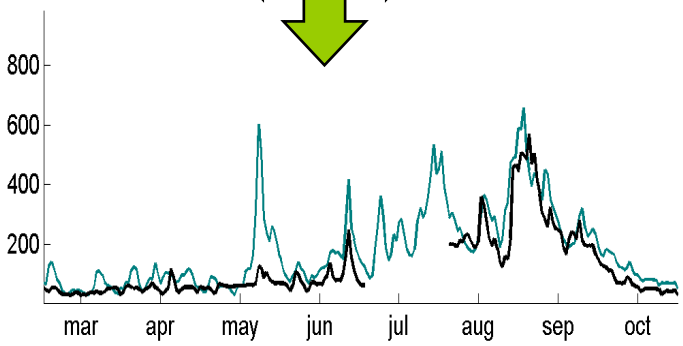
Hydrol. Model

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

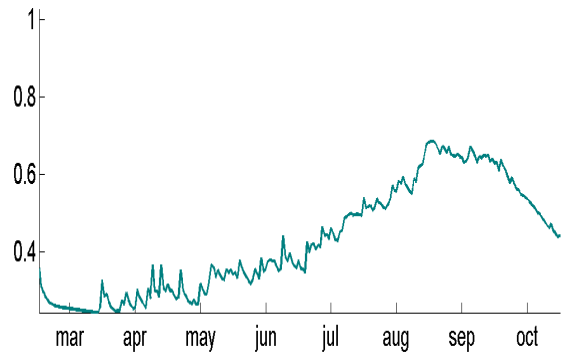
Model-based Monitoring Terrestrial Water Balance



Evapotranspiration [mm/a]



Surface Runoff [m³/s]



Soil mositure [%]

Research area: White Volta / West Africa

encarta world atlas

- 94000 km²

ke Volta

e

lay - October

vember – April

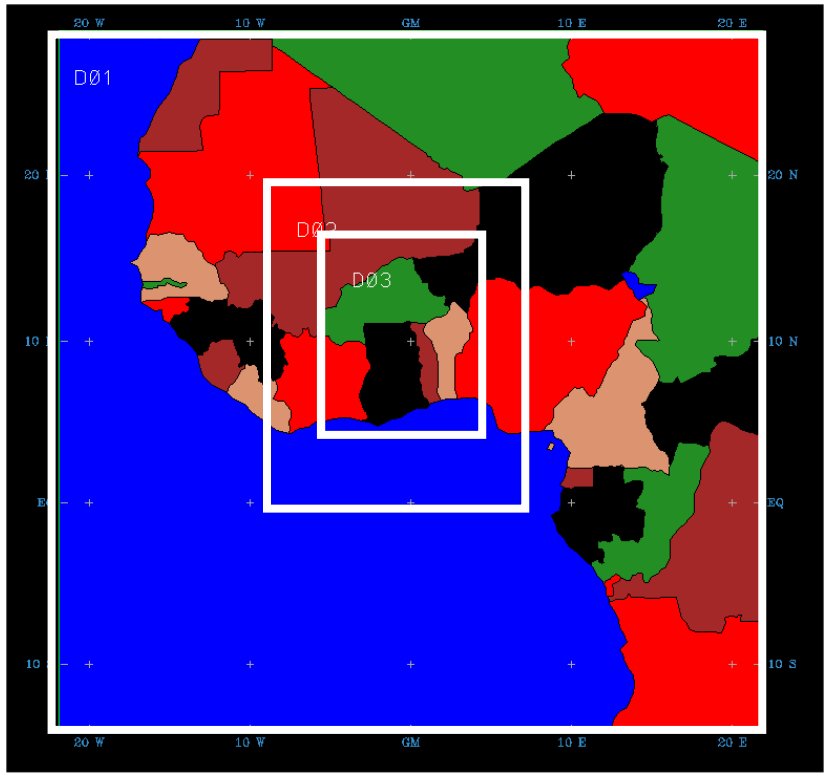
ecol. zones:
Savanna

Meteorological Model (near real time)

1. Mesoscale Meteorological Model MM5 (Penn State/NCAR)

Characteristics:

- Non-hydrostatic dynamics
- Multiple nesting capability
- Four dimensional data assimilation



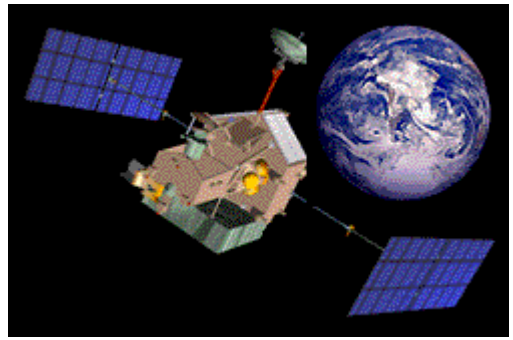
Setup:

- Global atmospheric fields:
  operational GFS–(NCEP) analysis
- 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
- Assimilation of radiosounding in domain 1
- One-way nesting (D1→D2→D3)
- Operational mode (http://www.glowa-volta.de): **near real time hindcast!**

TRMM (1 month delay)

2. Tropical Rainfall Measuring Mission



- measuring sub-, tropical rainfall through microwave and visible infrared sensors and precipitation radar
- joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA)
- start 1997, orbit 400 km

- **3B-42 Product: TRMM Merged HQ/Infrared Precipitation**

- 1. combination of microwave and infrared estimates
- 2. rescaled to match monthly rain gauge analysis (3B-43:GPCC)

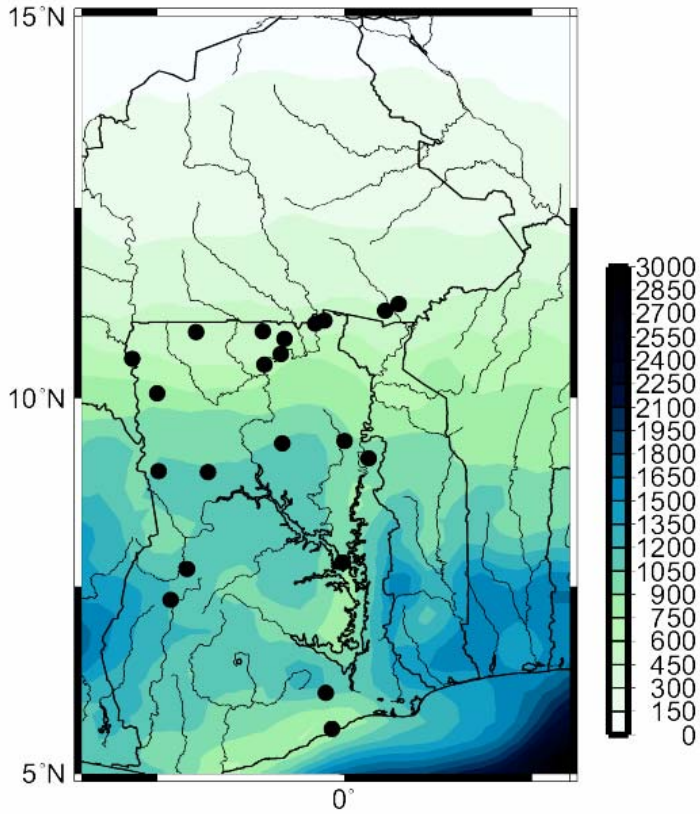
- 0.25°x0.25°, 3-h temporal resolution, 50°S to 50°N

OBSERVATIONS 2004 (1 year delay)

3. Observation data

- 20 stations in Ghana:
- Meteorological Service Ghana
- GLOWA-Volta project

- 2 Stations in Burkina:
- GLOWA-Volta project

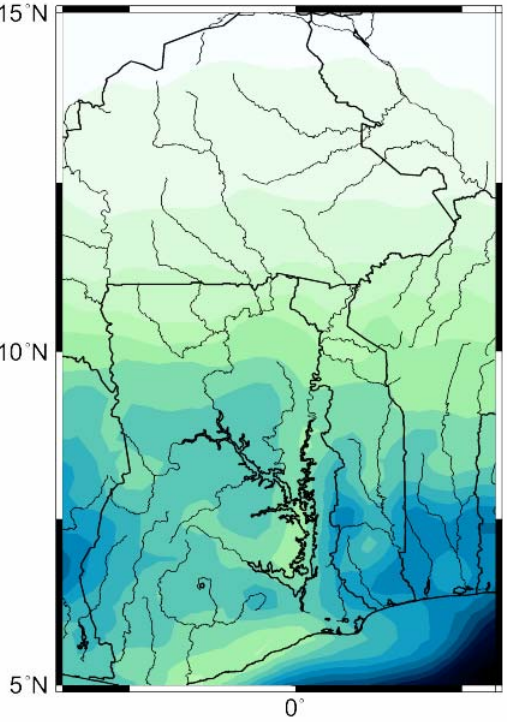


Results meteorological simulations

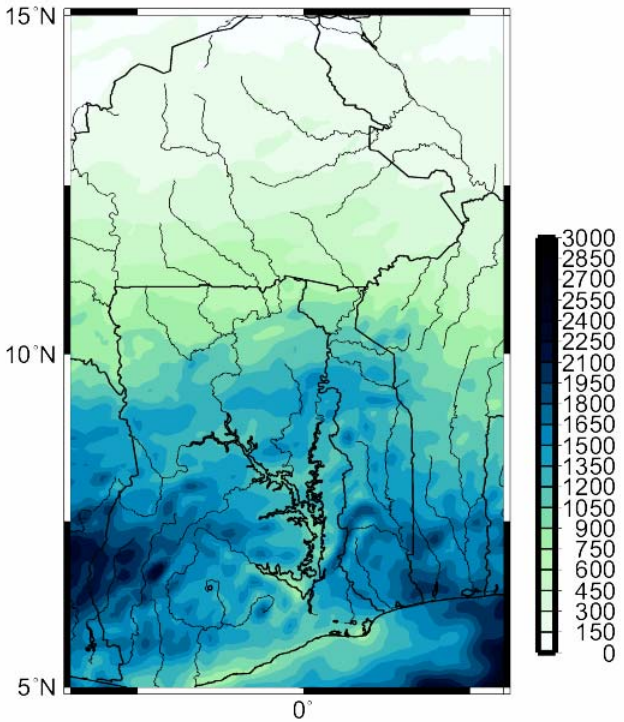
Annual precipitation 2004 [mm]

near real time
MM5

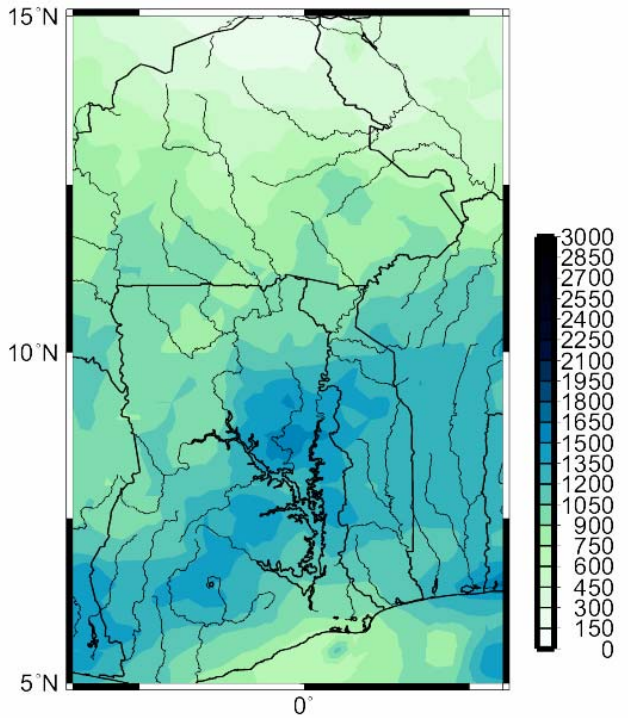
D2: 27 x 27 km



D3: 9 x 9 km



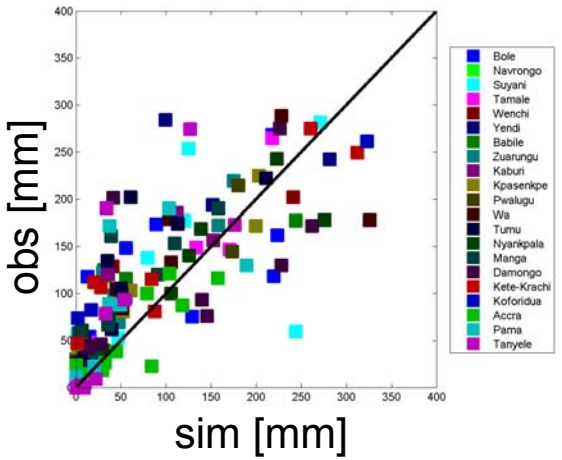
1 month delay
TRMM: scaled
0.25°



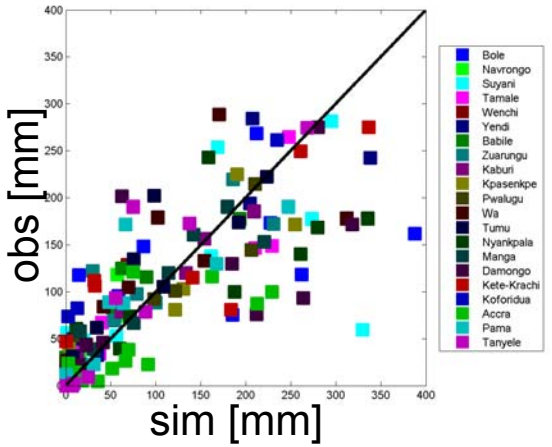
Validation meteorological simulations
monthly sums [mm]

near real time

D2:

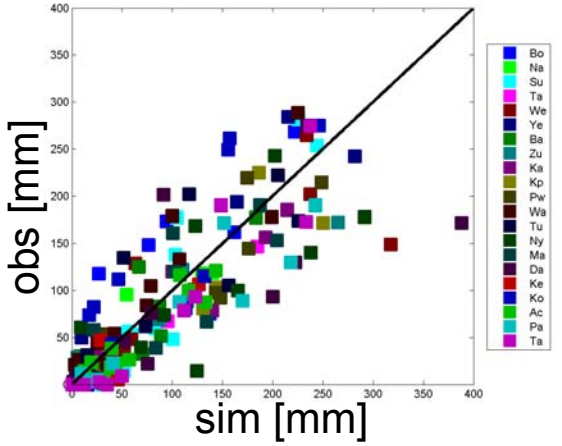


D3:

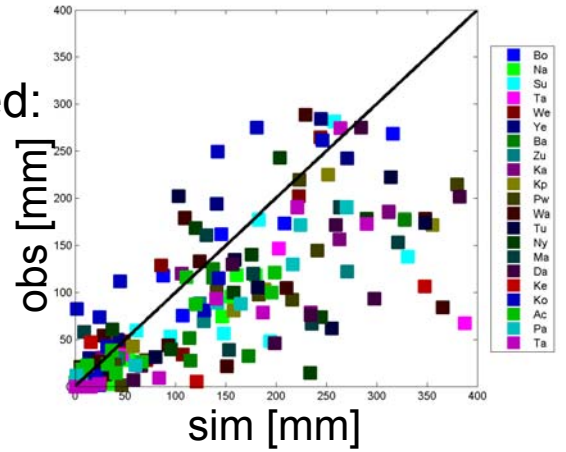


1 month delay

TRMM:



TRMM un-scaled:



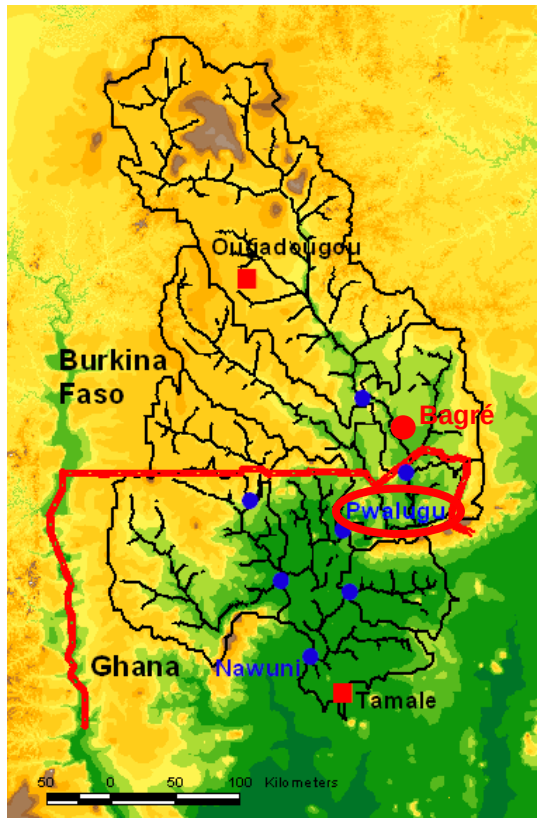
Application to hydrological simulations …

Distributed Hydrological Model

Water balance Simulation Model ETH: WaSiM-ETH (Schulla)

Physically based algorithms for most process descriptions

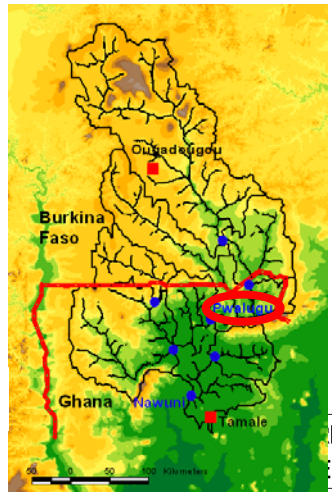
- Evapotranspiration: soil and vegetation specific (Monteith; Brutsaert)
- Flow through unsaturated zone (Richards)
- Suction head & hydraulic conductivity (van Genuchten)
- Discharge routing: cinematic wave
- 2-dim groundwater model dynamically coupled to unsaturated zone



Setup White Volta basin

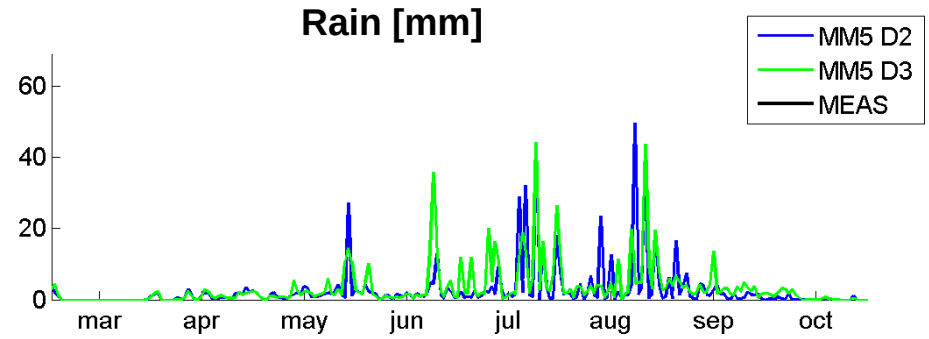
- spatial resolution: 1x1 km²
- temporal resolution: daily
- subdivision into sub-catchments

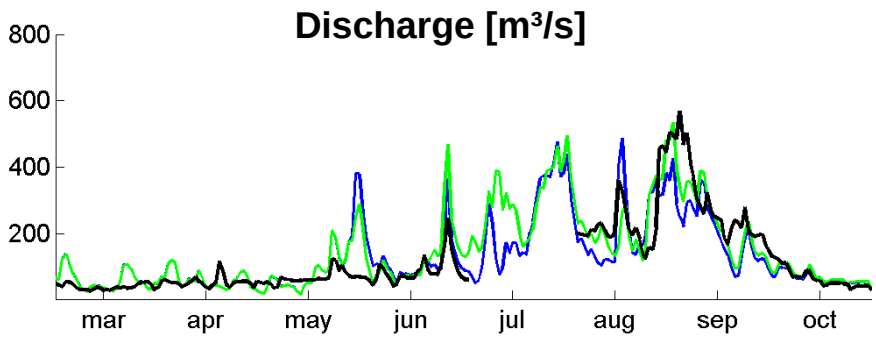
Results hydrological simulations:
Pwalugu



near real time:

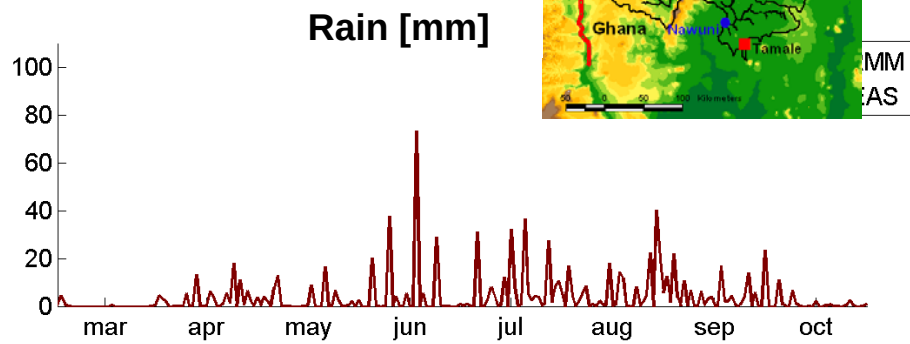
MM5 output

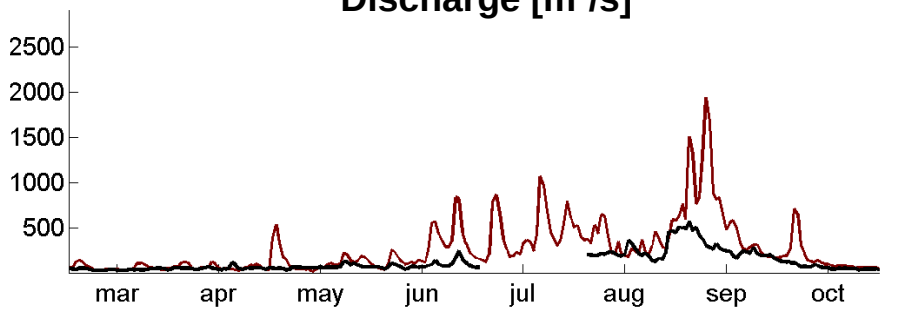




1 month delay:

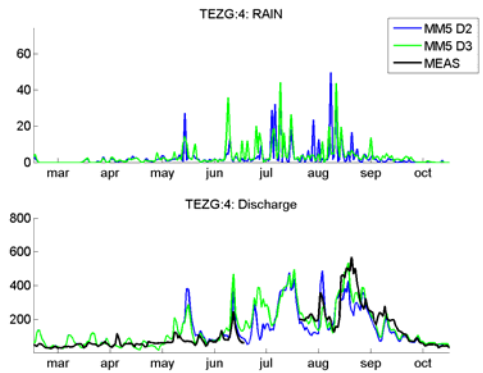
TRMM



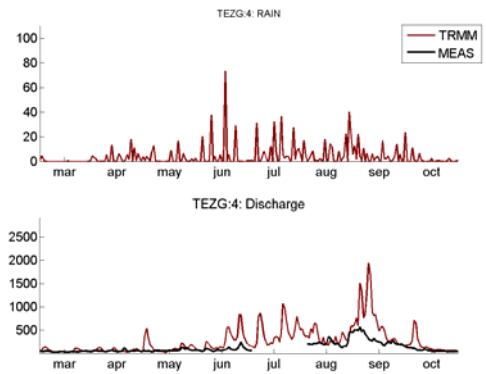


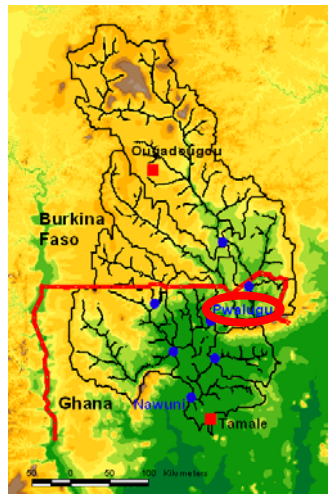
Results hydrological simulations:
Pwalugu

near real time: MM5

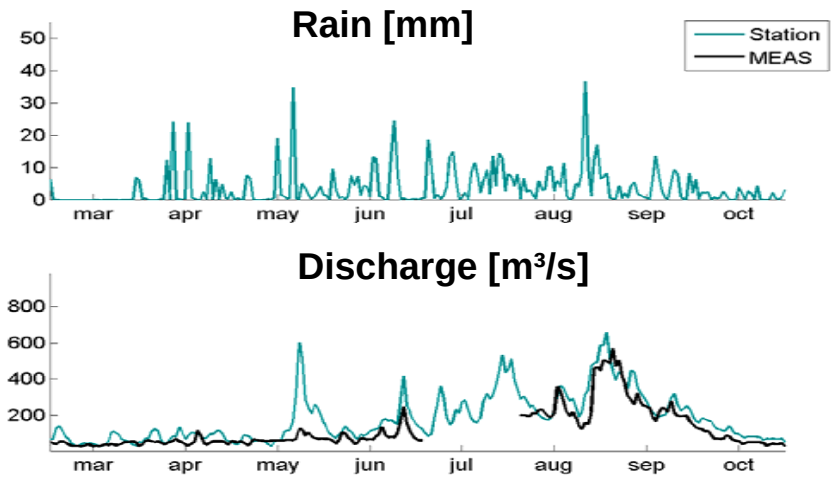


1 month: TRMM





1 year: stations



Nash-Sutcliffe-coefficients:

D2: 0.58

D3: 0.70

TRMM: -4.13

Stations: 0.49

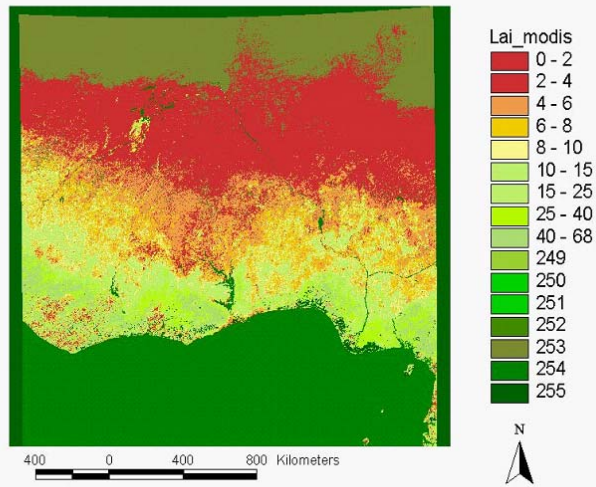
Water balance simulations using different land surface data sources

- Hydrological modeling requires land surface parameters (LAI, albedo, roughness length …)
- Standard literature values sometimes imprecise for specific areas
- Satellite remote sensing provides worldwide spatially information on land surface properties
  (e.g. MODIS entire earth every 2 days)

➢ Use of satellite derived gridded land surface properties data in hydrological modeling

➢ Composites of Albedo (16 days) and LAI (8 days) grids are analyzed, aggregated to monthly means, and imported into hydrological model

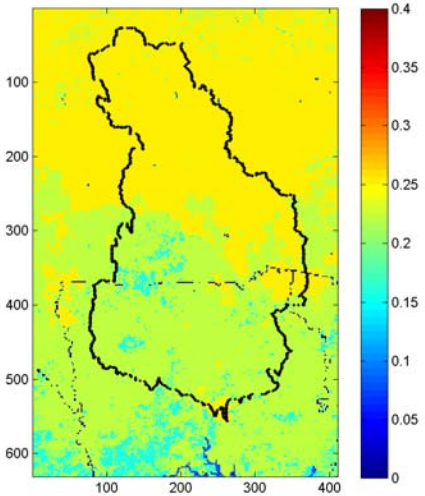
example: LAI



Albedo:
standard literature vs. MODIS 2004

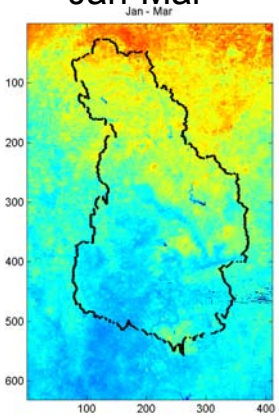
Standard literature

Albedo only depending on LU type

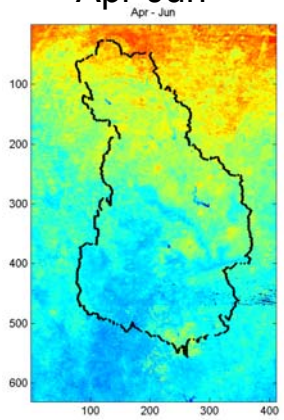


Albedo 3 month-mean (MODIS)

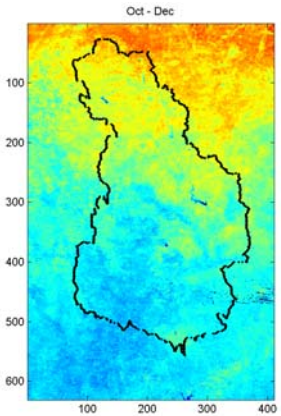
Jan-Mar



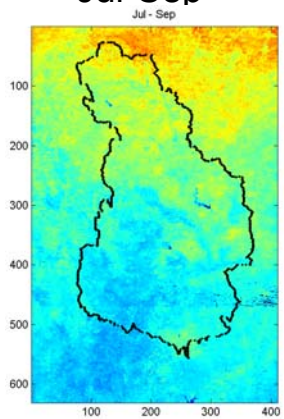
Apr-Jun



Oct-Dec

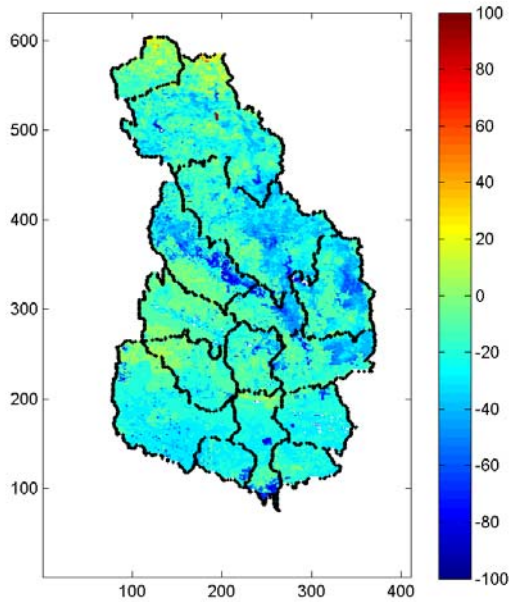


Jul-Sep



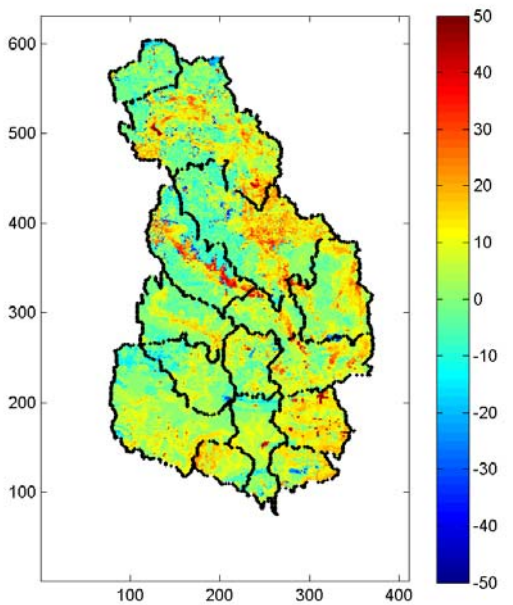
Albedo:
annual differences: standard literature minus MODIS

ETR_{Stand} - ETR_{MODIS} [mm]



Total basin:	-2%
Sub-Catchm.	-2% – 0%
10 x 10 km	-10% – 5%

$Qtotal_{Stand}$ - $Qtotal_{MODIS}$ [mm]

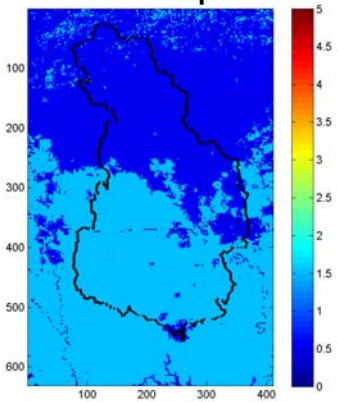


Total basin	6%
Sub-Catchm.	0% – +14%
10 x 10 km	-20% – +30%

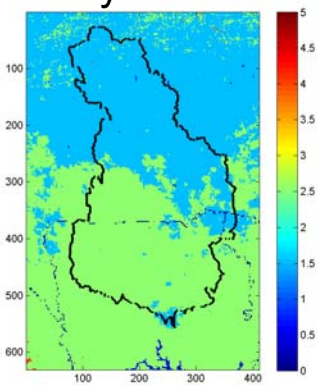
Leaf Area Index:
standard literature vs. MODIS 2004

standard literature

dry season: Nov - Apr

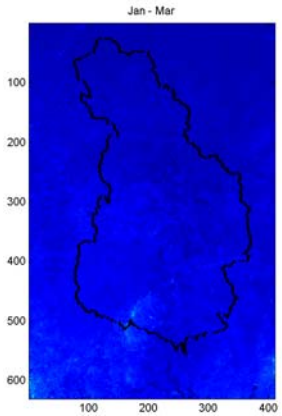


rainy season: May - Oct

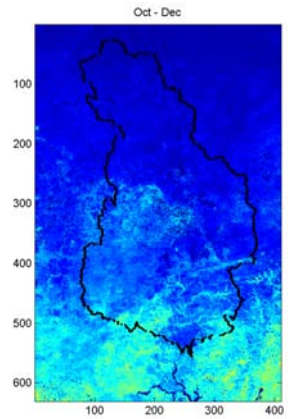


LAI 3 month-mean (MODIS)

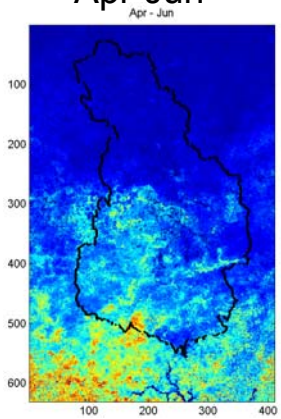
Jan-Mar



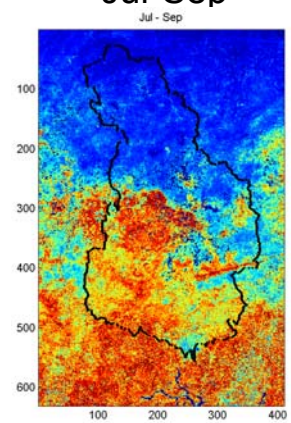
Oct-Dec



Apr-Jun

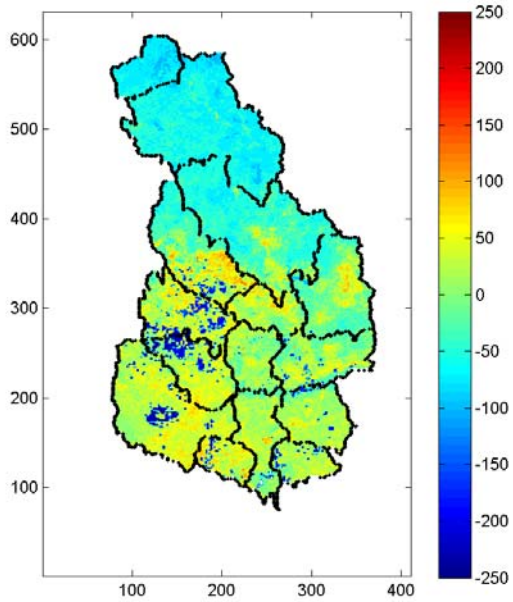


Jul-Sep



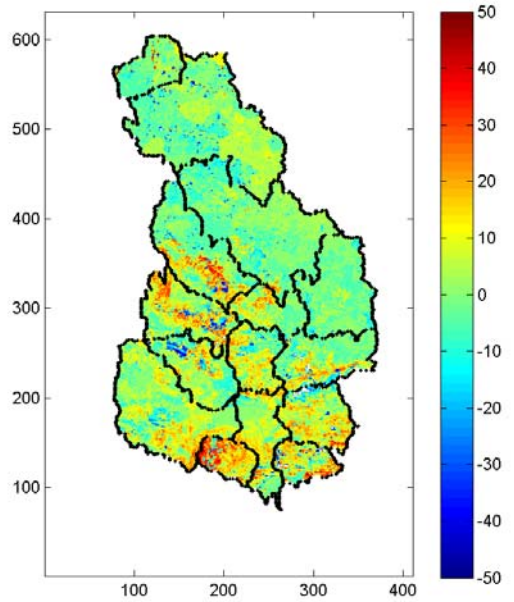
Leaf Area Index:
annual differences: standard literature minus MODIS

ETR_{Stand} - ETR_{MODIS} [mm]



Total basin	-0.2%
Sub-Catchm.	- 7% – +3%
10 x 10 km	-15% – +10%

$Qtotal_{Stand}$ - $Qtotal_{MODIS}$ [mm]



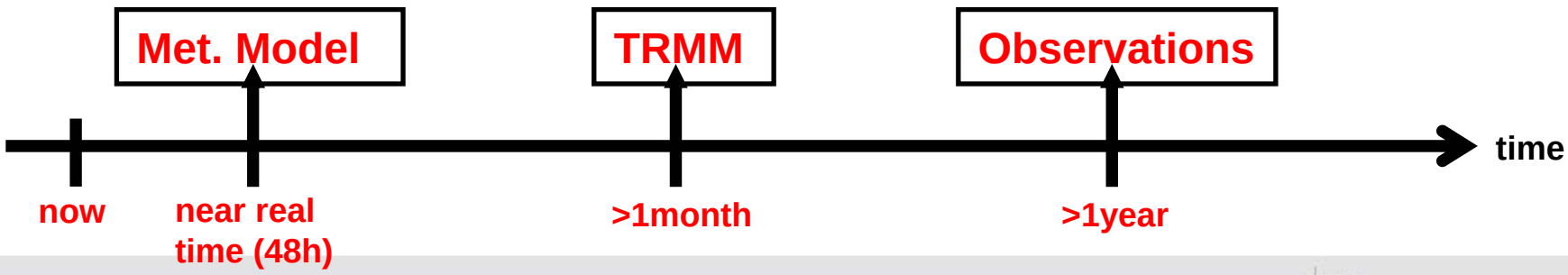
Total basin	3%
Sub-Catchm.	0% – +17%
10 x 10 km	-10% – +30%

Summary

- **Assimilation of satellite derived land surface properties in hyd. modeling**
  - ➢ local differences in spatial distribution of water balance variables
  - ➢ on sub-, catchment scale differences decrease

- **Using different meteorological input data**

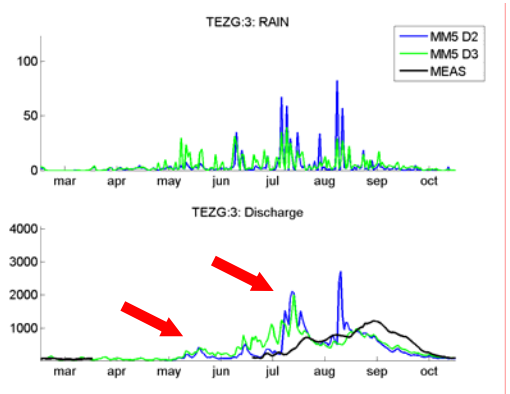
  - ➢ near real time: regional meteorological model output
    MM5 is able to provide met. input for hyd. sim. (CPU & storage intensive)
  - ➢ 1 month delay: TRMM 3B42
    for this study: no improvements compared to MM5 near real time
  - ➢ 1 year delay: Observations
    best performances
  - ➢ using TRMM & observations: further meteorological data are required
  - ➢ selection of meteorological input depends on task (time!!)



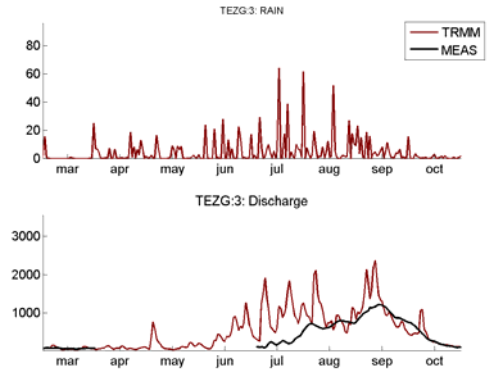

Thank you for
your attention !!

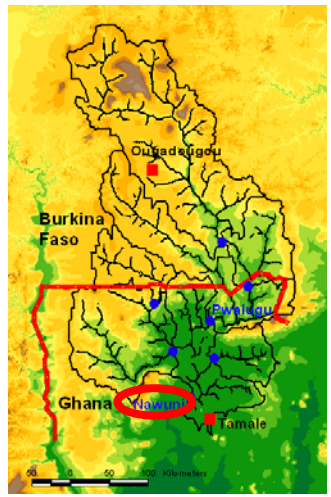
Results hydrological simulations:
Nawuni

near real time:MM5

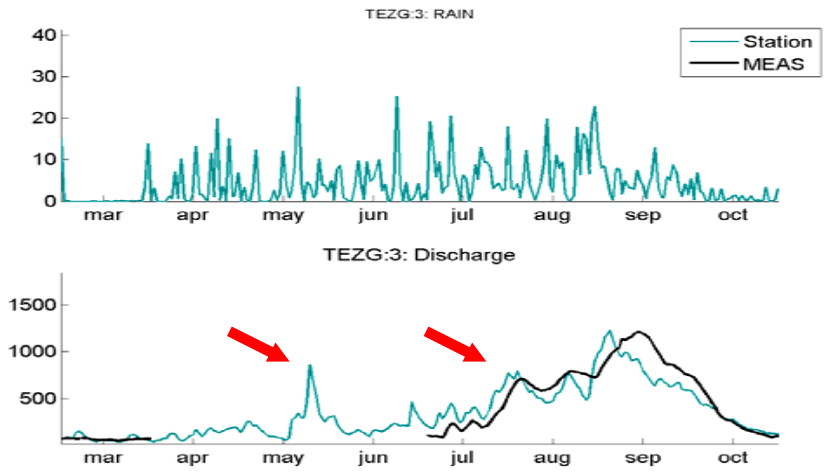


1 month: TRMM





1 year: observations



Nash-Sutcliffe-coefficients:

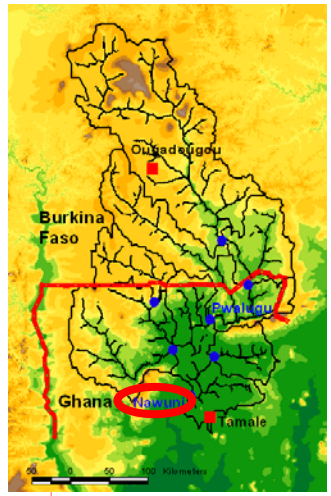
D2: -0.59

D3: -0.11

TRMM: -0.84

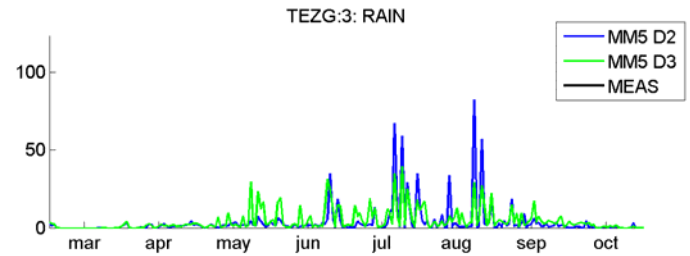
Stations: 0.82

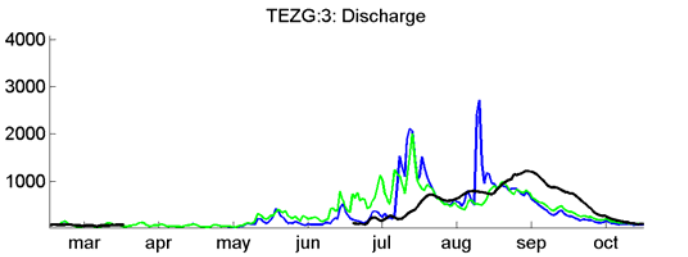
Results hydrological simulations:
Nawuni



near real time:

MM5 output





1 month delay:

TRMM