Taking the Step from a Large-Scale Hydrological Model (West-Africa) to a Continental Model (Africa)

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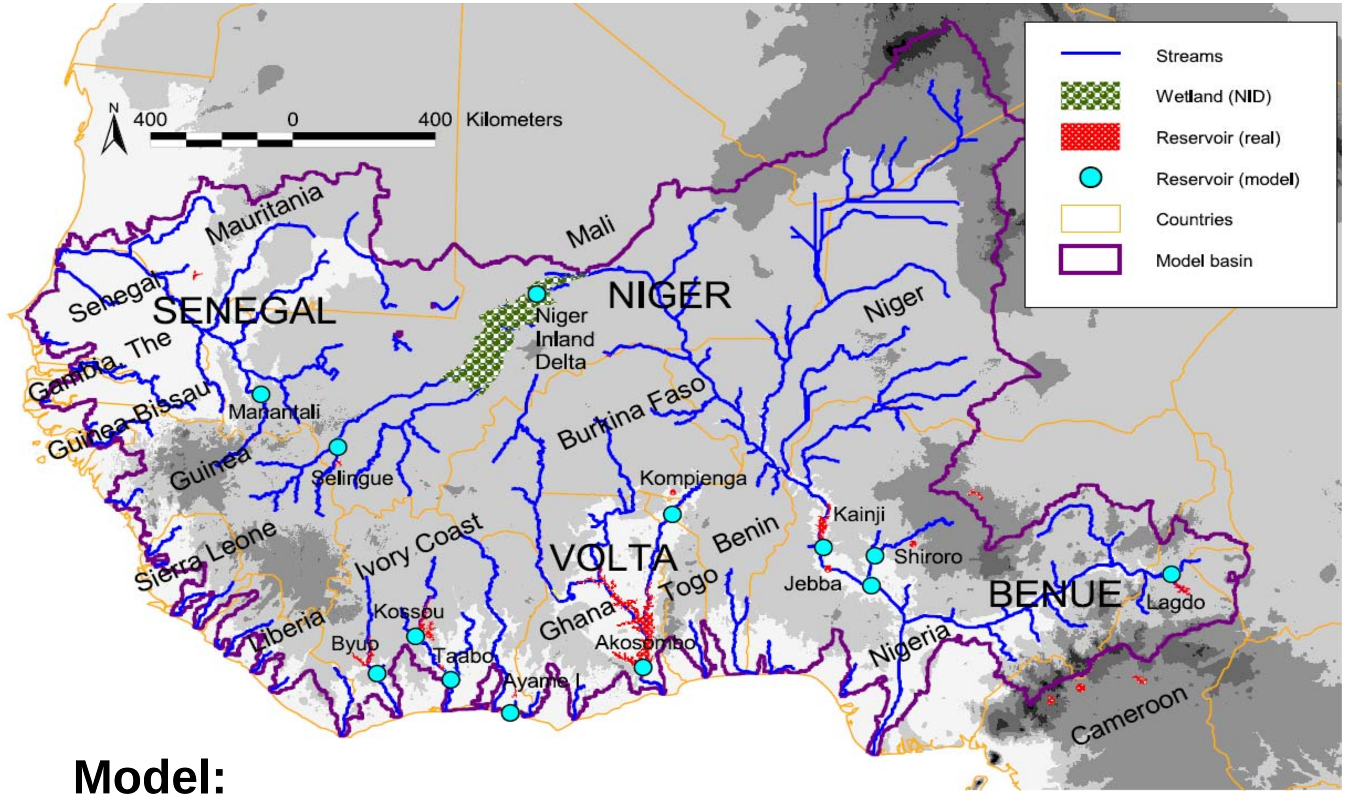
Project: Hydrological modeling of global freshwater availability using SWAT

Objectives

- quantification of the country-based freshwater availability at a **sub-country level** on a **monthly time-scale**
- **quantification** of the **uncertainty** associated with the freshwater figures
- calculate the spatial **green water storage** (soil water) and the **green water flow** (actual ET) distribution and its temporal trends at a (sub-)country level
- using the calibrated hydrological model for **studies of county-based food and water security**
- extend the calibrated global hydrological model to study the **global water quality**

Case study: West Africa



Study site:

- basin area: 4 mil. km^2
- hyper-arid to humid
- desert to rainforest (mainly savannah)
- challenging due to comparably small database

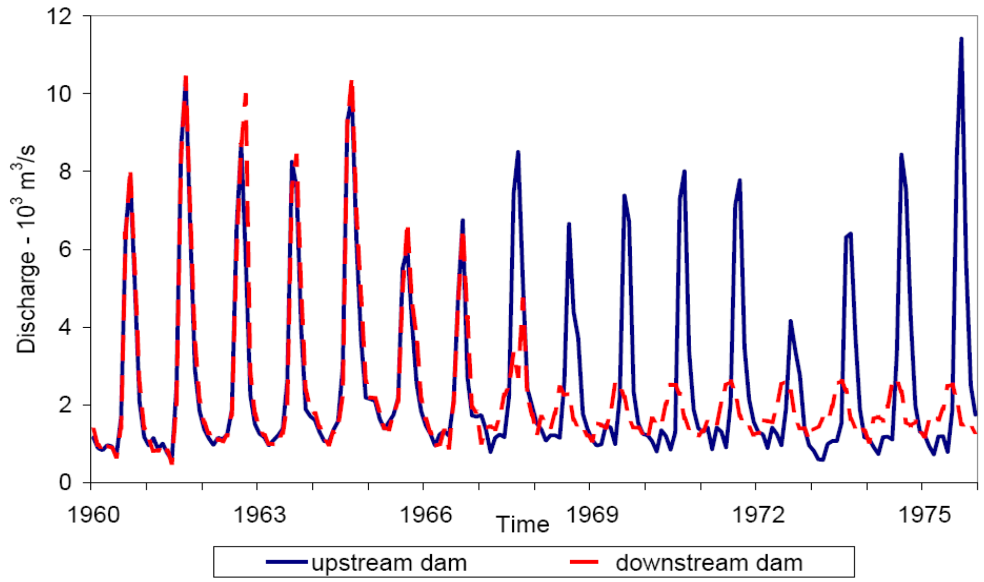
Model:

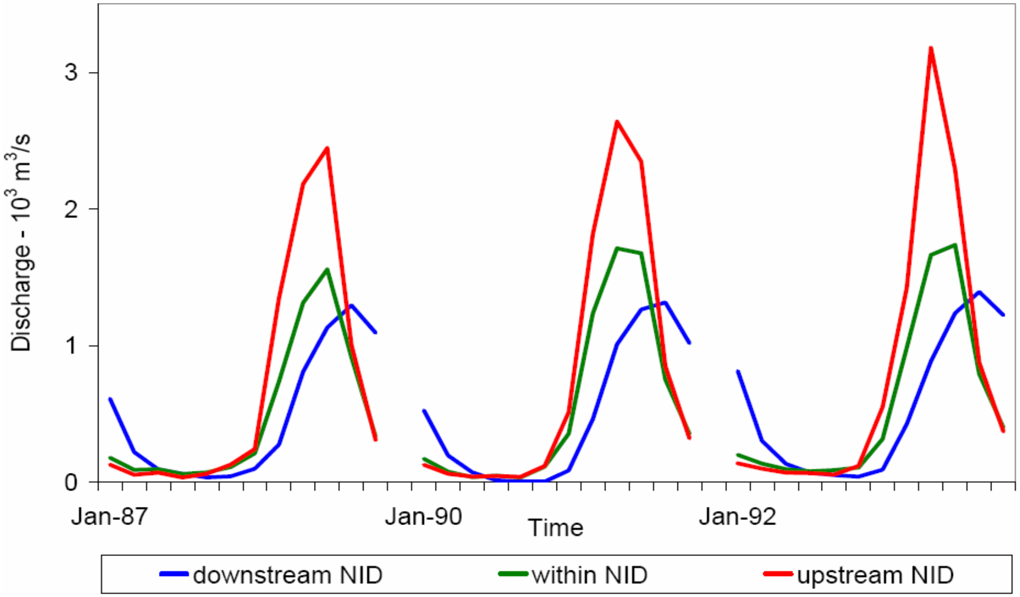
- Used only globally and freely available data and information
- Delineation into 292 sub-basins using the **ArcView interface**
- Use **daily weather generator algorithm** (dGen, *Schuol and Abbaspour, 2007*) in combination with CRU 0.5° gridded monthly climate data order to obtain daily climate station data

Important but problematic…

Inclusion of **reservoirs** in the model

e.g. observed discharge up- and downstream of the Aswan dam in Egypt





Inclusion of **wetlands** in the model

e.g. observed discharge up-, within and downstream of the Niger Inland Delta

Calibration and uncertainty analysis procedure

- **Monthly** measured river discharge at 64 stations in West-Africa is used for calibration and validation
- Spatially distributed parameters→many parameters→restriction necessary
  - Sensitivity analysis→reduction of the number of parameters
  - Aggregation of parameters: Changing of parameter groups
- Need for a multi-site automated calibration and uncertainty analysis procedure: **SUFI-2** (*Abbaspour et al., 2004 and 2006*)
- Need for an efficient method for the assignment and updating of parameters in the model-input-files: **SWAT-SUFI-Interface** (*Yang et al., 2006*)

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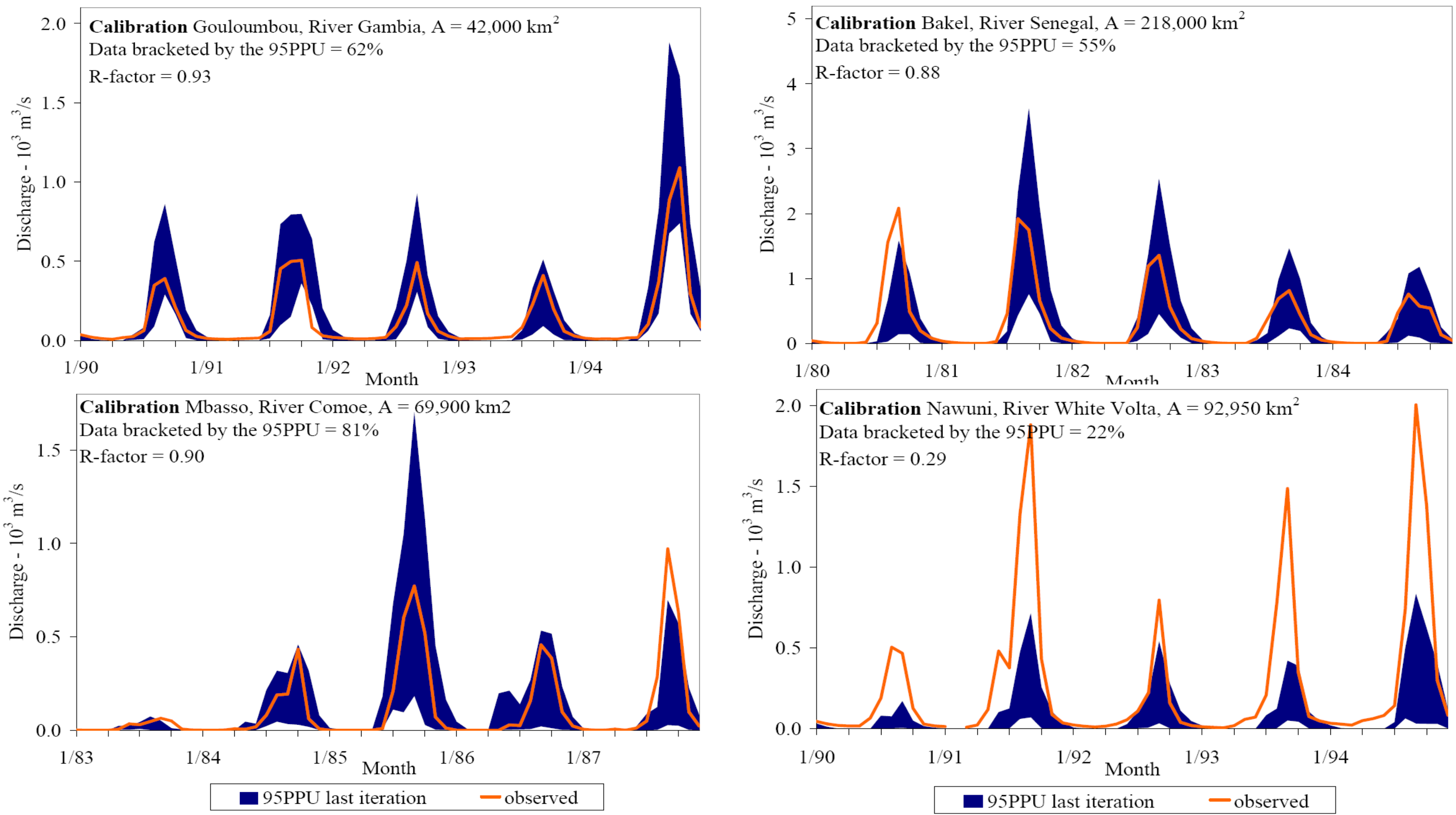
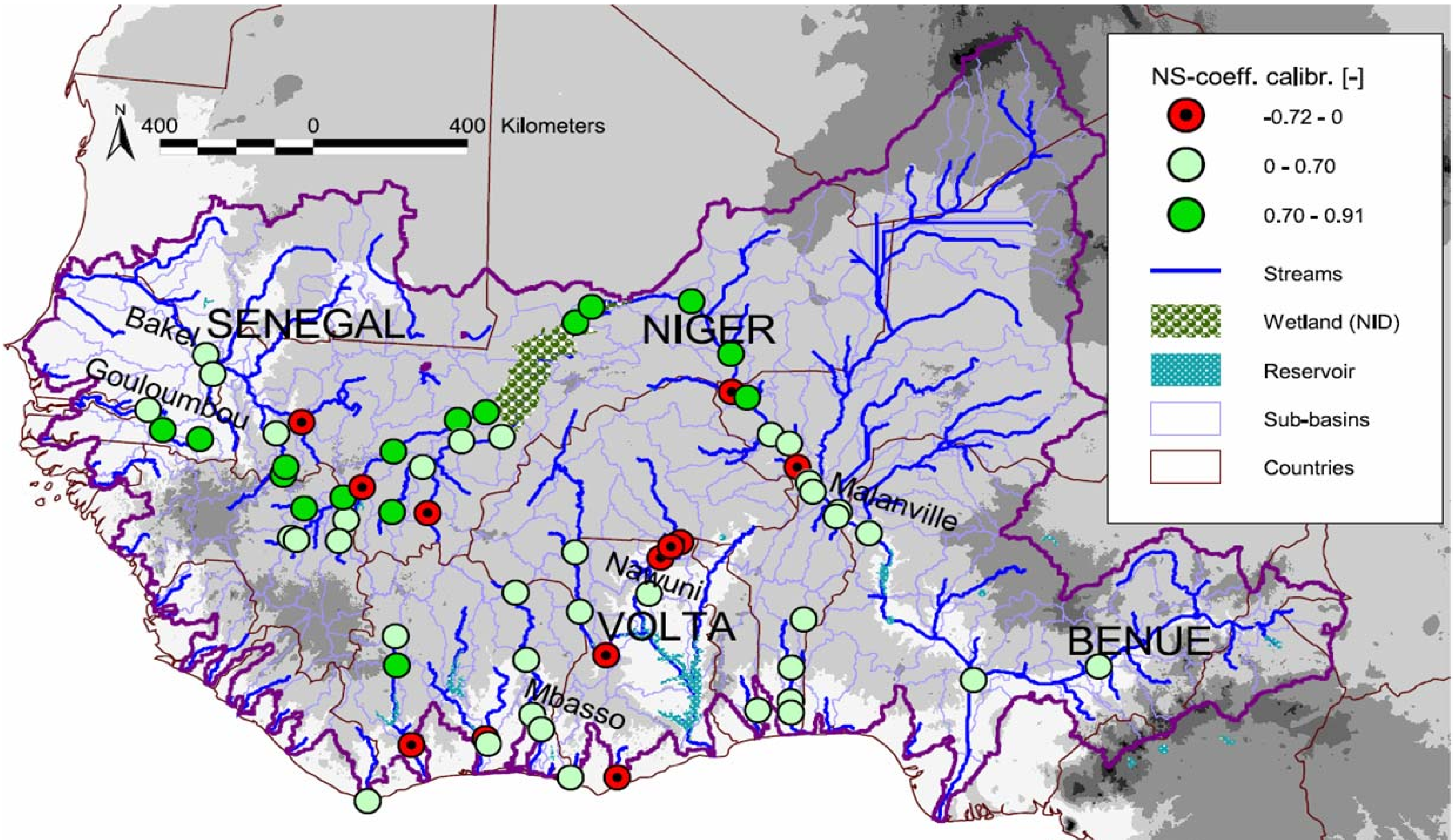
Calibration results for selected stations

Extracts of the monthly calibration results for selected stations showing the 95% prediction uncertainty intervals along with the measured discharge



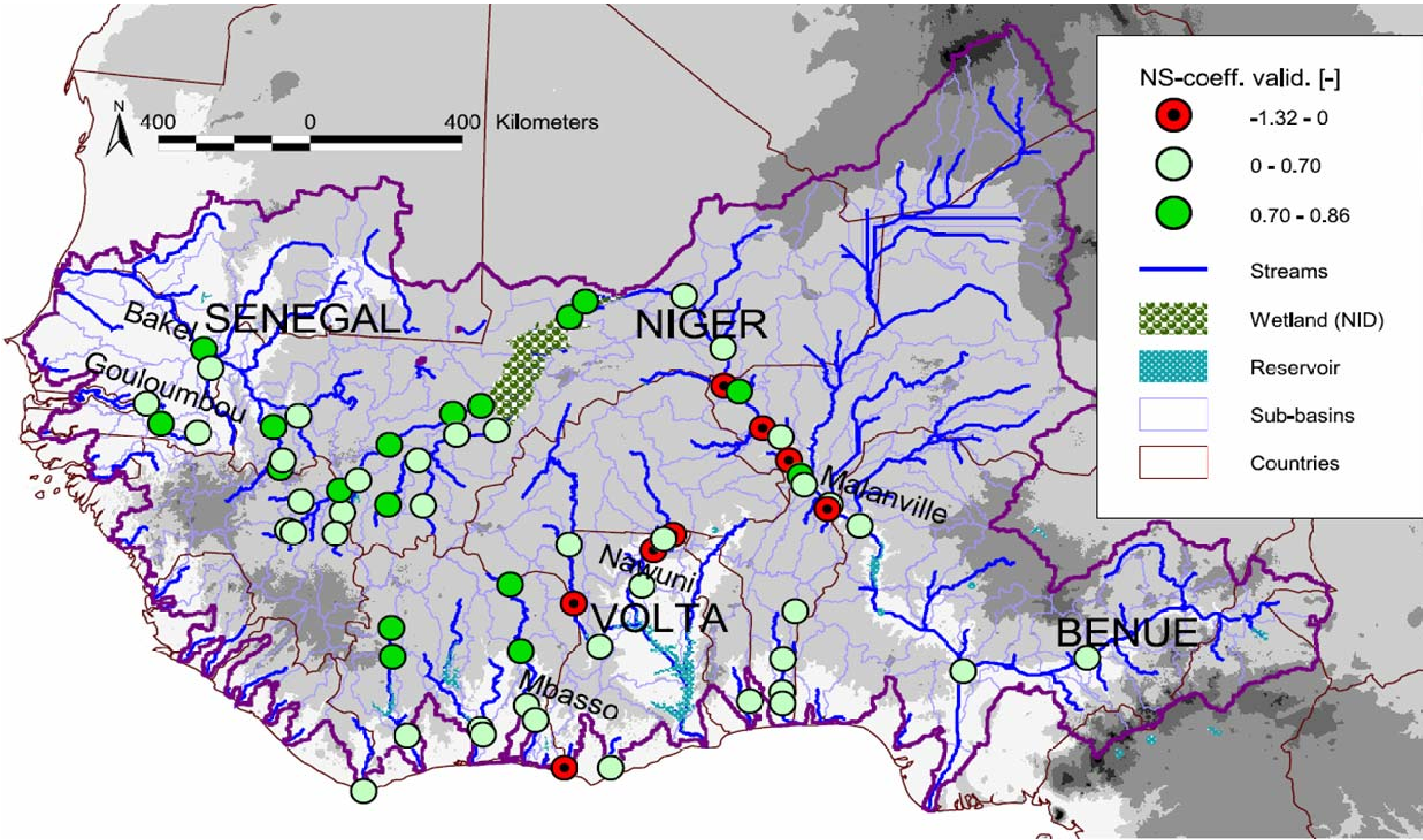
NS coefficient – calibration period

Nash-Sutcliff coefficient of the “best” simulation of the monthly runoff for the **calibration** period at all 64 stations.

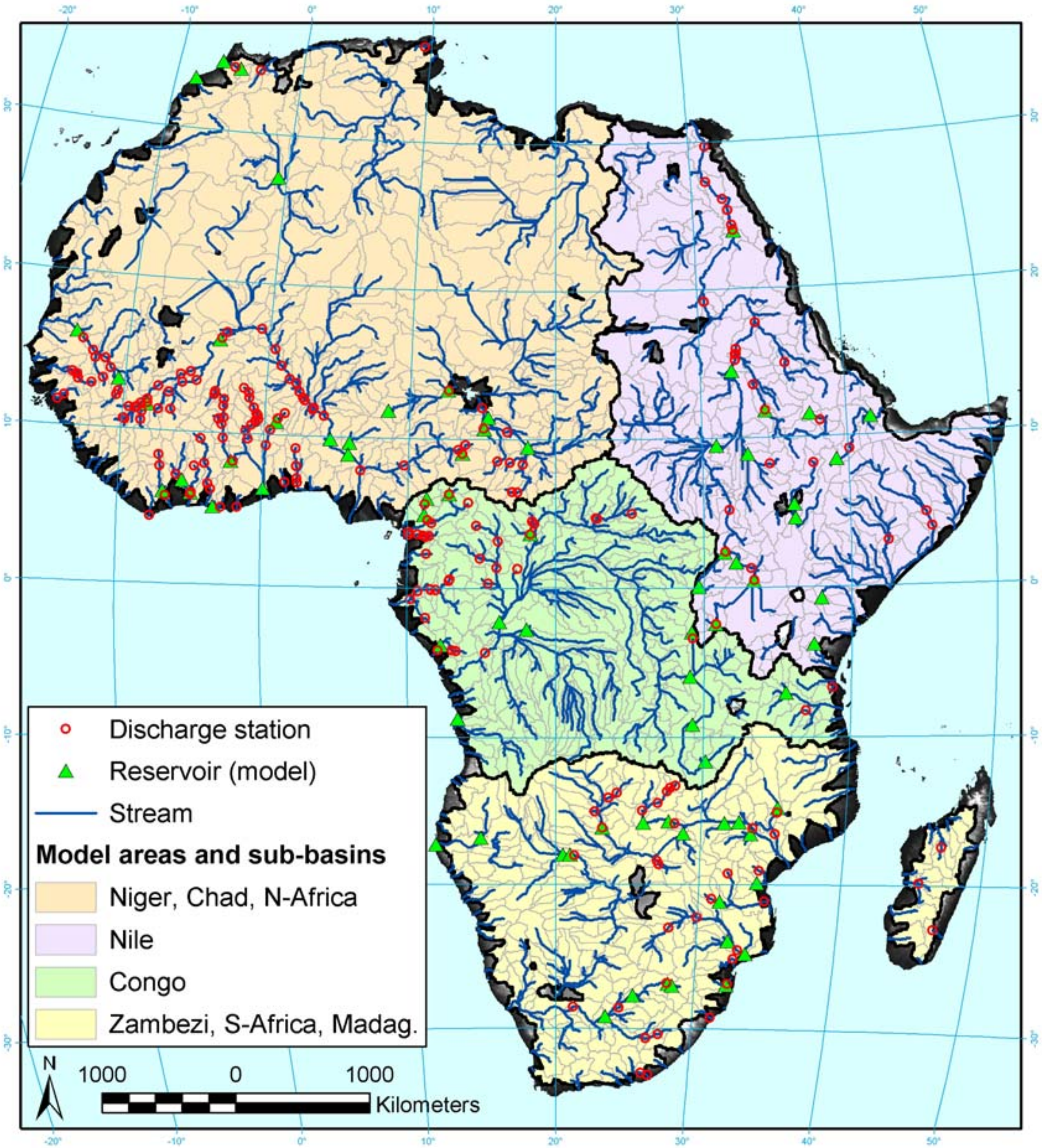


NS coefficient – validation period

Nash-Sutcliff coefficient of the “best” simulation of the monthly runoff for the **validation** period at all 64 stations.



The Africa continental model



- Delineation of Africa into 1496 sub-basins using the **ArcSWAT interface**
- 208 stations with monthly observed river discharge
- Use dominant soil, landuse and slope in each subbasin
- Divided the continent into **4 model areas**, which are independently calibrated but within the same model frame

SUFI-2 Calibration of the Africa model

- **Efficiency criteria**: weighted version of the coefficient of determination r^2

$$vr^2 = \begin{cases} |b| \cdot r^2 & \text{for b} \le 1 \\ |b|^{-1} \cdot r^2 & \text{for b} > 1 \end{cases}$$

- **Objective function** *g:* n-station sum of vr^2; stations are differently weighted (w)

$$g = \sum_{i=1}^{n} \left(w_i \cdot \left(vr^2 \right)_i \right)$$

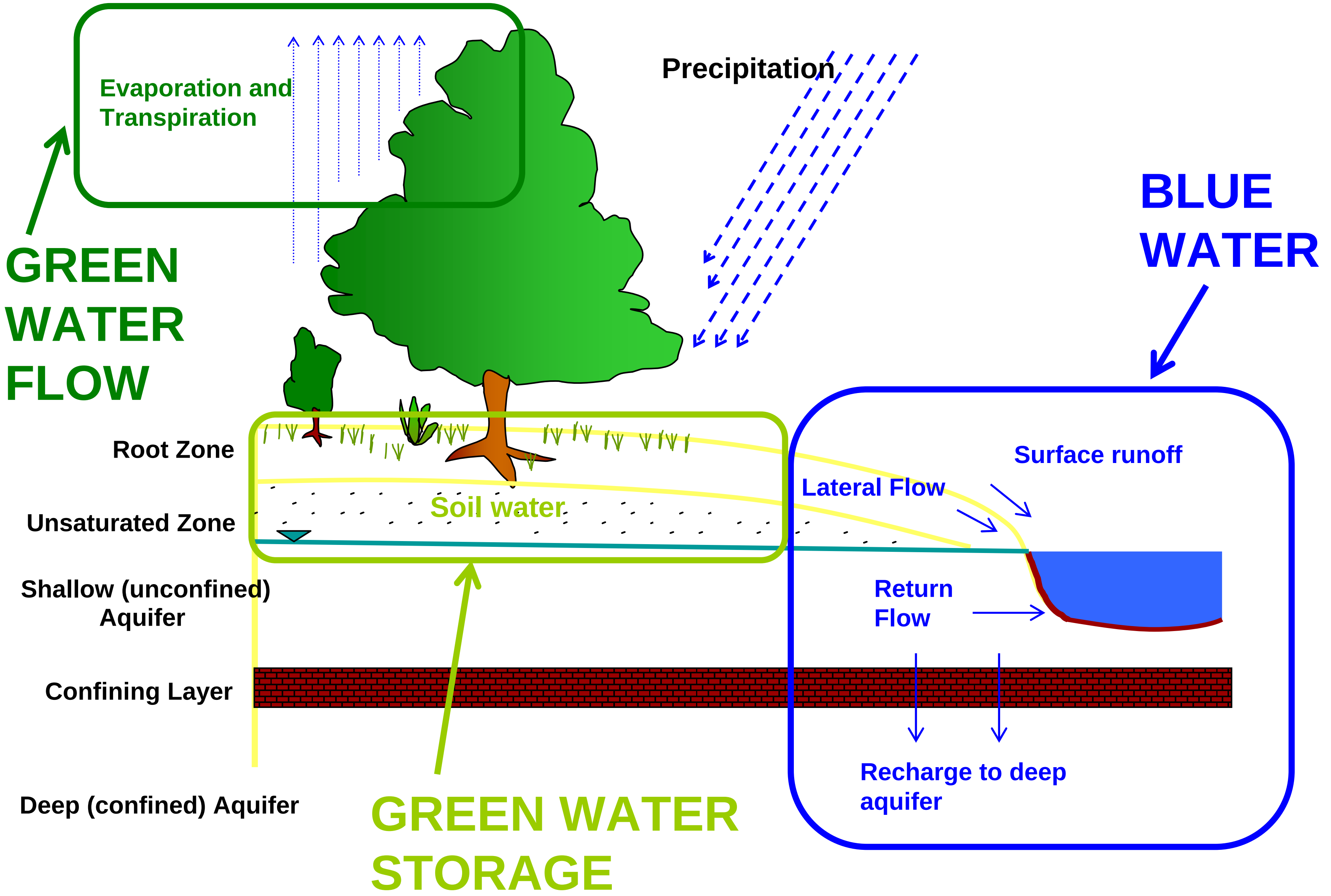
- **Weight at the different stations** depends on contributing area A and number of observations s

$$w_i = \sqrt{\frac{\left(A_i - \sum_{j=1}^{n} A_{up,j} \right) \cdot s_i}{s_i + \sum_{j=1}^{n} s_{up,j}}}$$

Calibration goals:

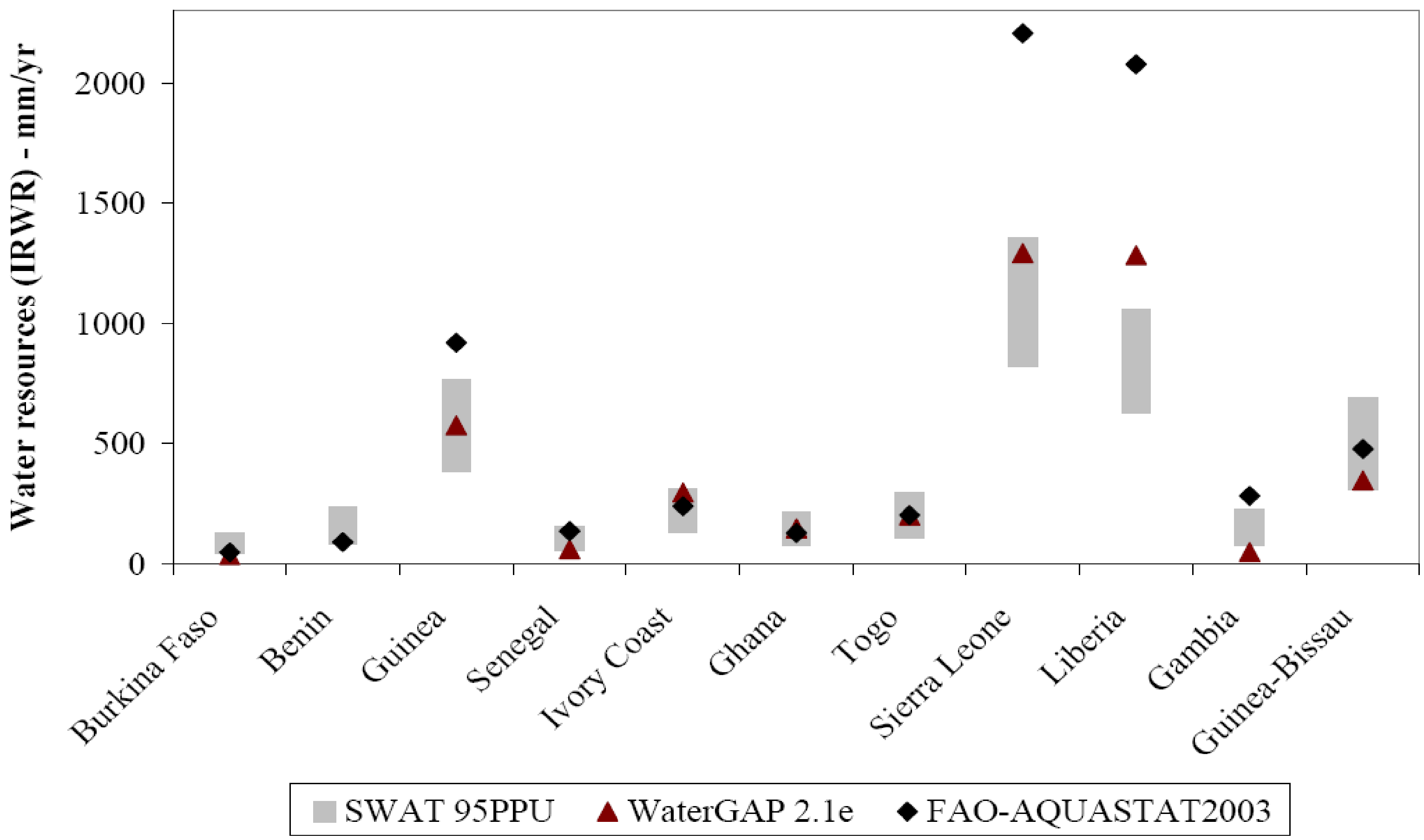
- Maximize objective function g
- Minimize parameter ranges while bracketing a reasonable percentage of the measured data in the 95% prediction uncertainty (95PPU) band

Freshwater availability: Blue and green water



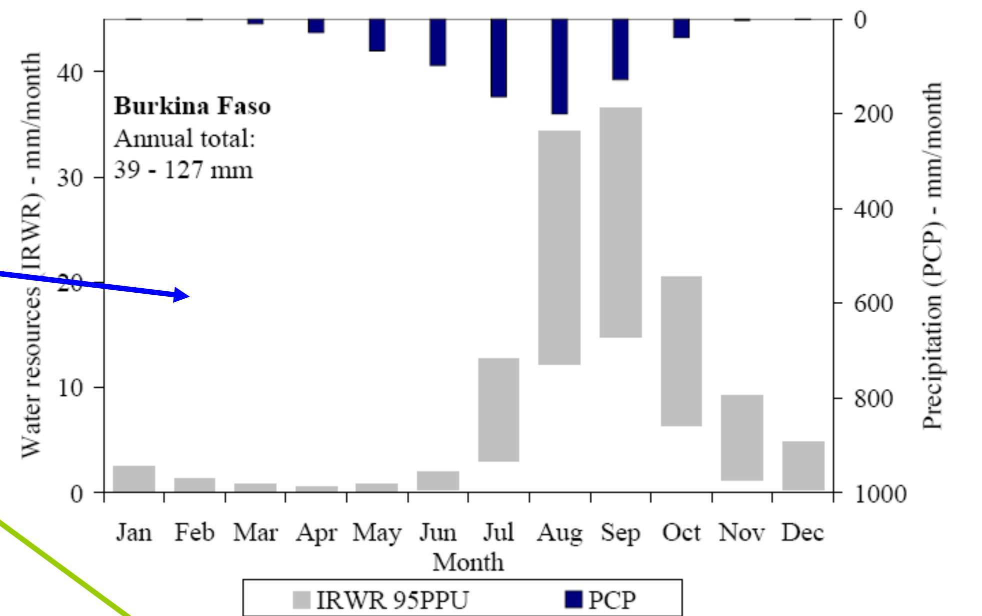
Internal renewable water resources (Blue water)– mm/year

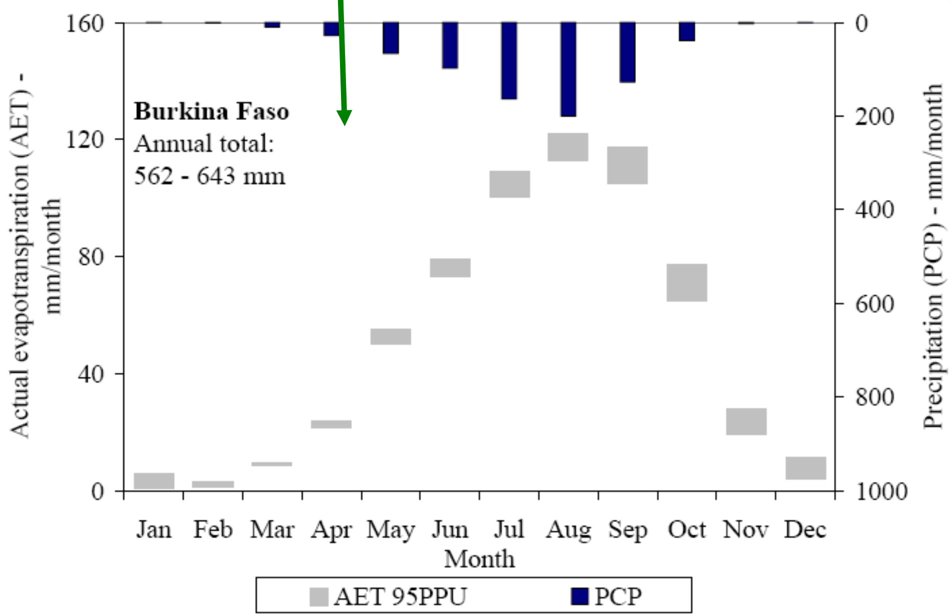
Comparison of the computed 95PPU intervals for the annual average (1971-1995) of the internal renewable water resources (IRWR) for selected countries with the results from the FAO assessment and the WaterGAP model in **mm year^{-1}**

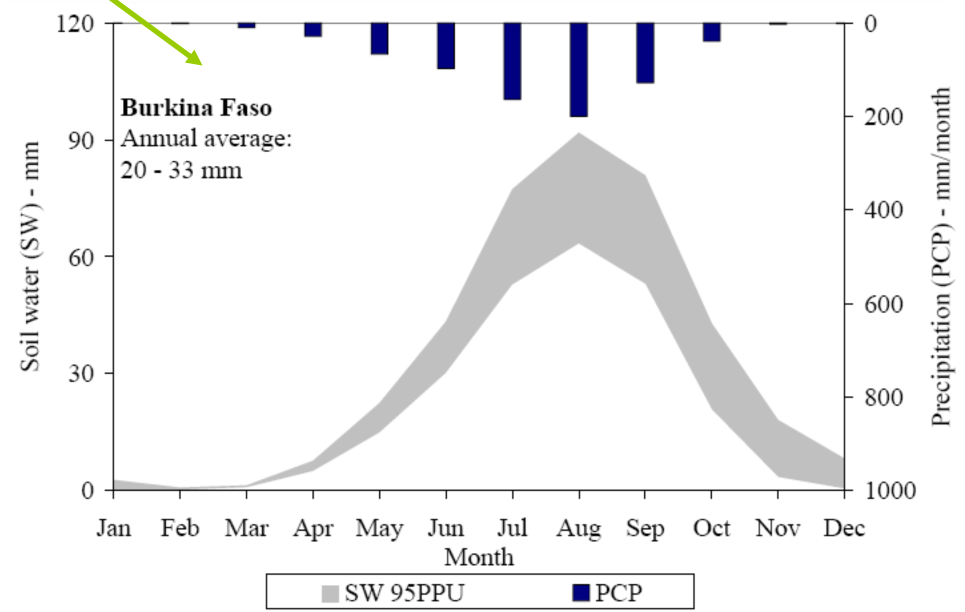


Average monthly 95PPU intervals – Burkina Faso

Average (1971-1995) monthly 95PPU intervals of the internal renewable water resources (IRWR, blue water), the actual evapotranspiration (AET, green water **flow**) and the plant-available soil water (SW, green water **storage**)

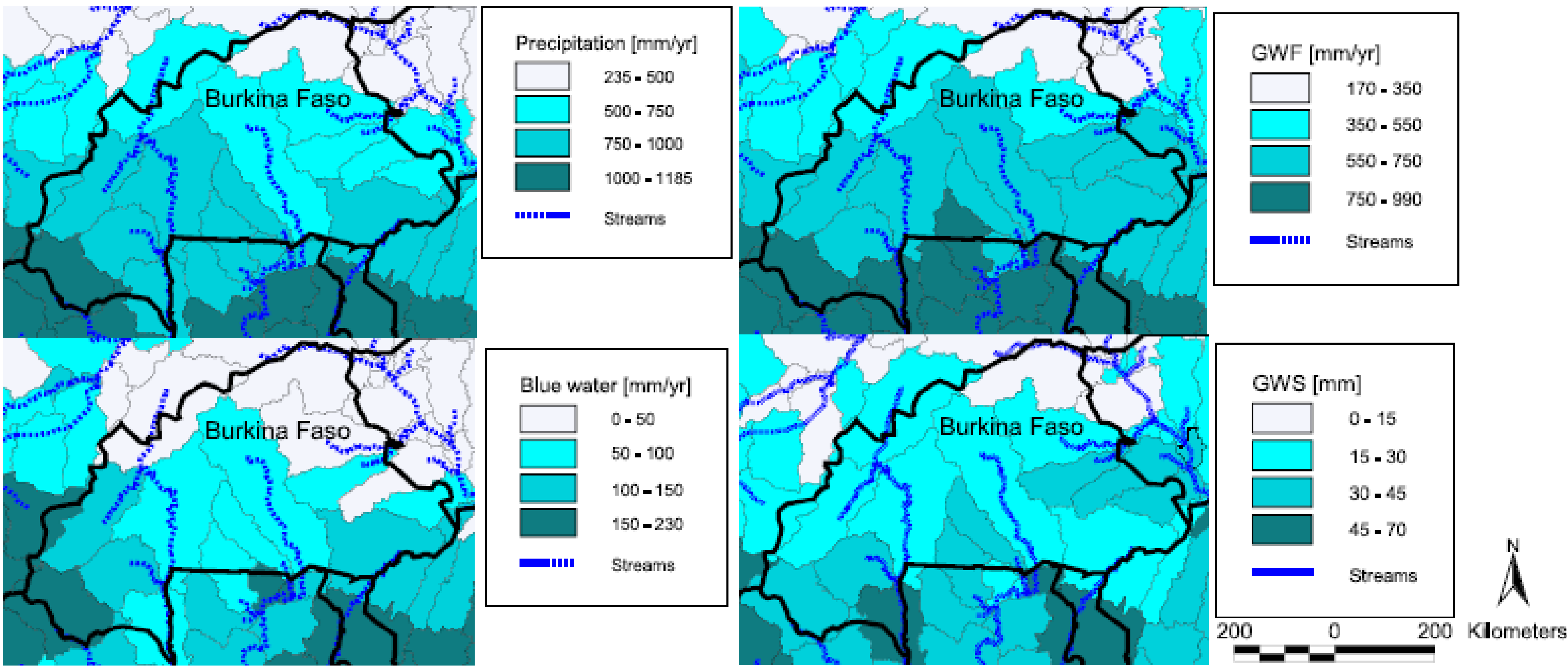






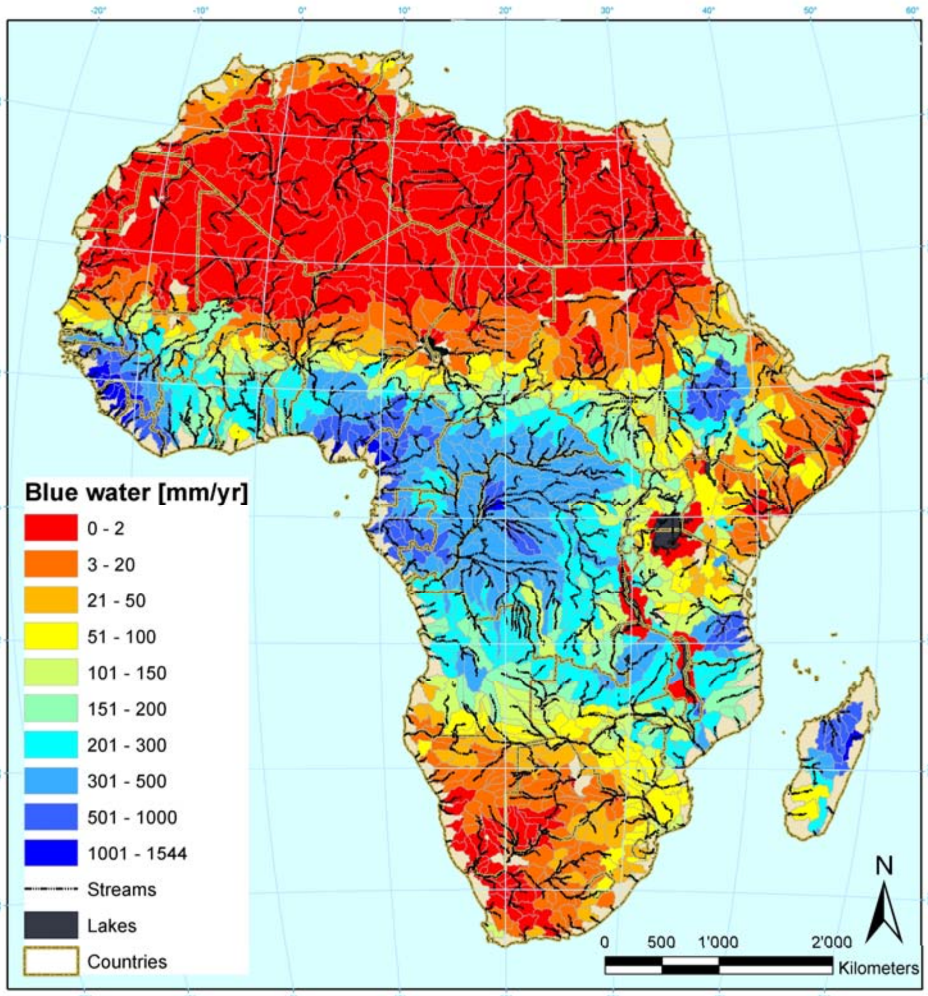
Regional differences in Burkina Faso

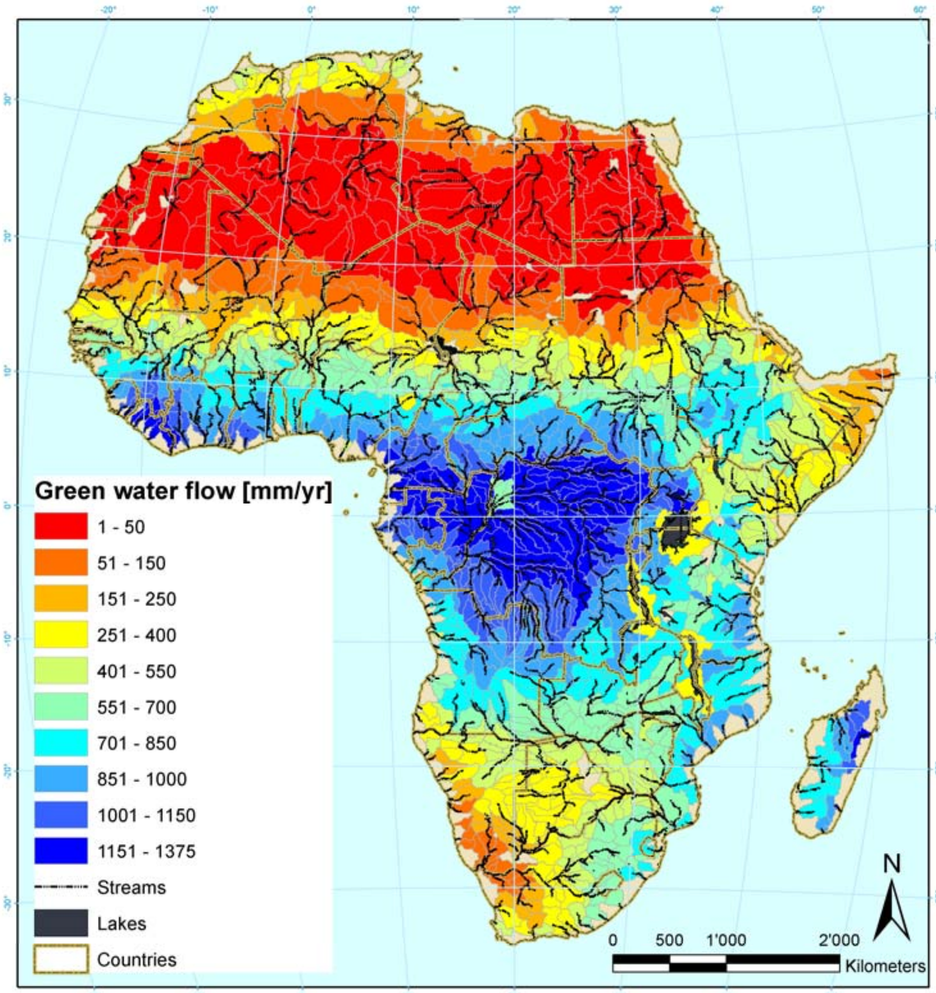
Average (1971-1995) regional differences of the annual precipitation, the blue water and the green water flow (GWF) as well as the average green water storage (GWS) in Burkina Faso



The continental picture

Blue water

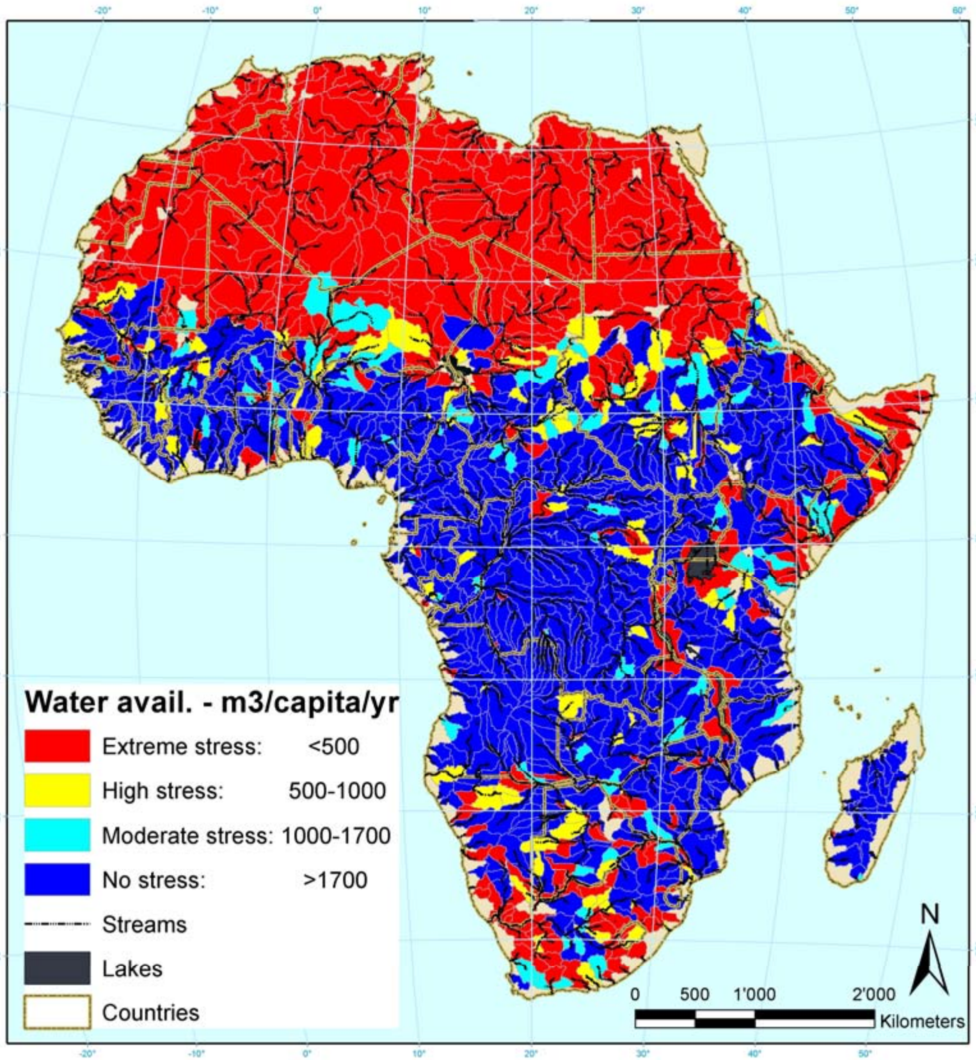




Green water flow

Nice model(s) – and now?

- Making use of the obtained information on the spatial and temporal variations of the sub-country-based freshwater availability in global and national strategic water planning and management – e.g. advanced studies concerning
  - water and food security
  - virtual water flow
  - scenario analysis
  - effects of climate change



Water stress level as an indicator for water scarcity

Conclusions

- SWAT can be used also for very large scale (continental) water quantity investigations, especially using the new **ArcSWAT**

- Main problem: **lack of information and data** on...

- For a (global) freshwater assessment it is not sufficient to focus only on the **blue water** – the **green water** is of utmost importance for sustaining ecosystem services and rainfed agriculture

- Given all the natural heterogeneity, presenting the **results as prediction uncertainty ranges** is quite logical – one number could be quite misleading

Outlook

- **go on with the other continents** in order to finally obtain a global picture

Thank you!