Vrije Universiteit Brussel

Evaluation of Climate Change Impacts on the Blue Nile Flows using SWAT

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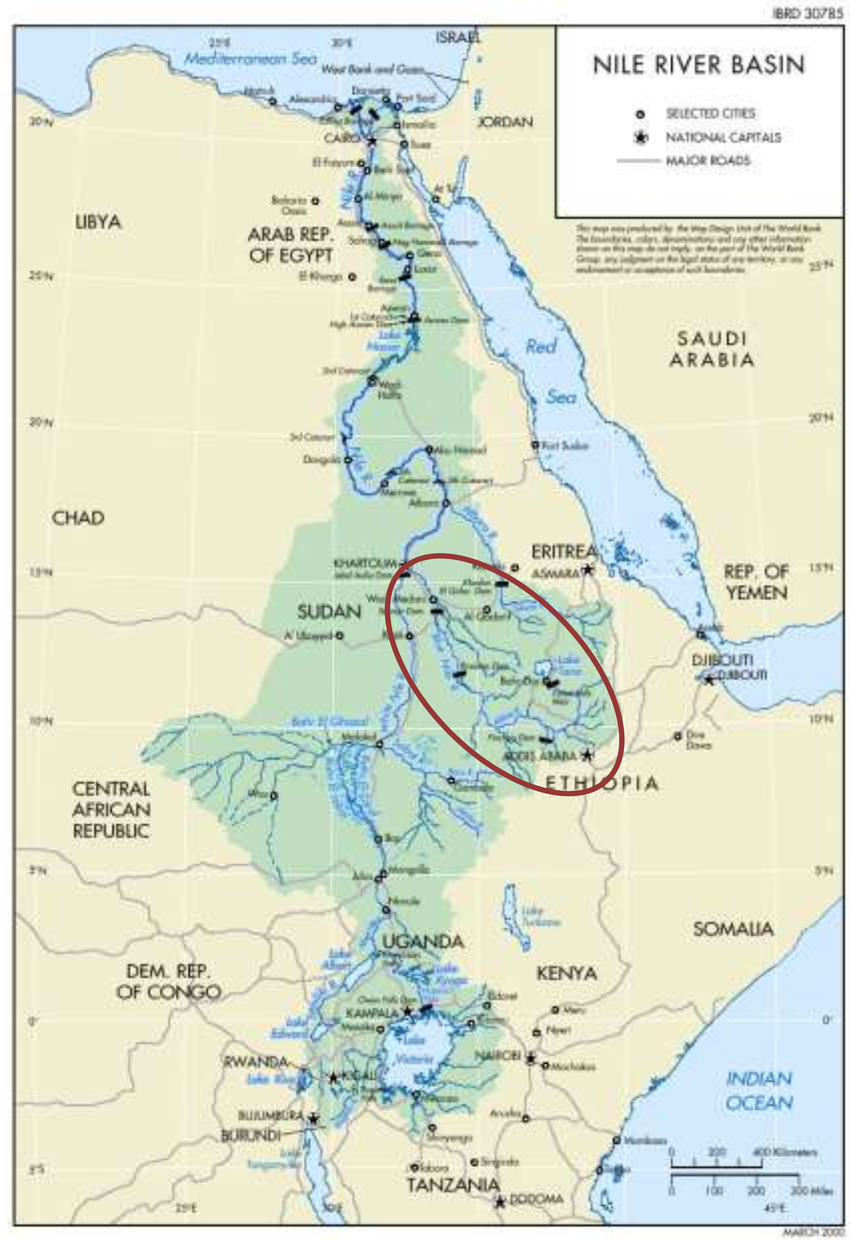
The Blue Nile River Basin

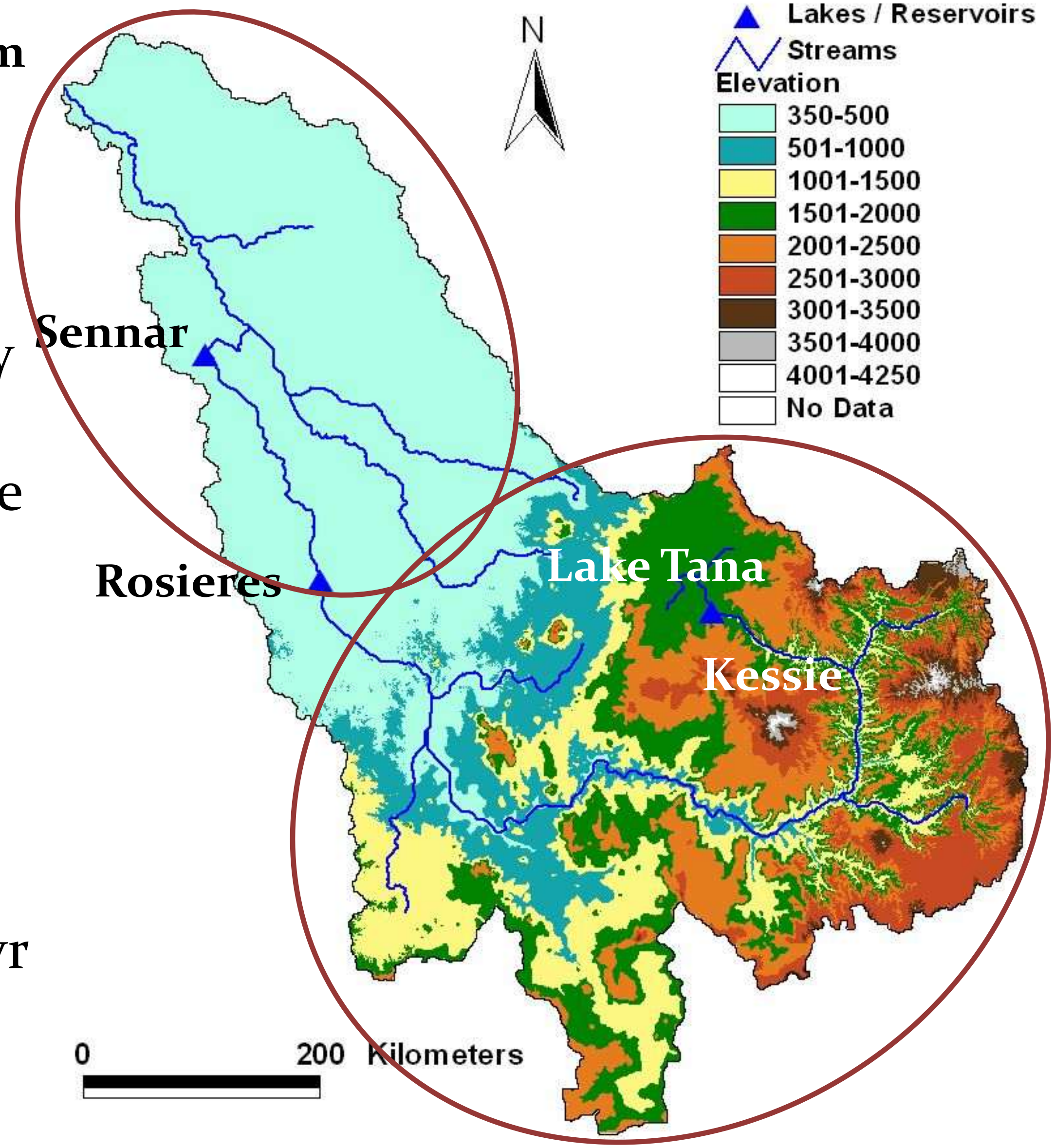
- 2nd biggest tributary of the Nile River
- Drains around 10% of the entire Nile river catchment
- Originates in Ethiopia and meets White Nile in Khartoum (Sudan)



Large and Climate Change Sensitive

- Drainage area around 310,000 km^2
- Transboundary river supporting 200 million human lives (Ethiopia, Sudan, Egypt)
- Contributes 60% of the Nile flow annually (Waterbury 1979; Sutcliffe 1999; Conway 2005)
- High topographical, climatic and hydrological variability
- Sensitive to climate change (Conway, 2005; Kim et al., 2008; Elshamy et al., 2009)

Salient Features



- Mix LULC: Savana, Barely vegetated and dryland/cropland/pasture
- Higher clay contents
- Mild slopes
- Low rainfall: 250 mm/yr
- High PET: 2400 mm/yr

- Two built reservoirs
- One natural lake
- Savana dominance
- Higher sand contents
- Steep slopes
- High rainfall: 1500 mm/yr
- Low PET: 1150 mm/yr

Objectives

- SWAT model for the entire river basin including lake Tana and built reservoirs
- Model evaluation and predictive uncertainties
- Assessment of climate change impacts on river flows by the year 2025

Input Data

- Observed monthly discharge series at 4 stations (GRDC)
- Daily precipitation and temperature data for 20 stations (EAWAG)
- Monthly statistics of wind, relative humidity and solar radiation (FAO)
- DEM, Landuse and DSN (1 km - USGS)
- Soil map (10 km - FAO)
- Lake / reservoir characteristics (RIBASIM Nile Model)
- Irrigation water withdrawals (FAO)

Quality Control

Homogeneity test at 95% significance level for the following datasets:

- Observed monthly discharge series
- Precipitation
- Temperature

Problematic temperature datasets

Methodology – Model Setup

- Implementation of Lake Tana in isolated subbasin
- 23 sub basins and 191 HRUs
- Reservoirs implementation using outflow release rates
- Irrigation water withdrawals as consumptive water use from reservoirs
- Model evaluation at monthly time step
  Calibration (1973-1978)
  Validation (1979-1982)
- Multi site sensitivity analysis and calibration

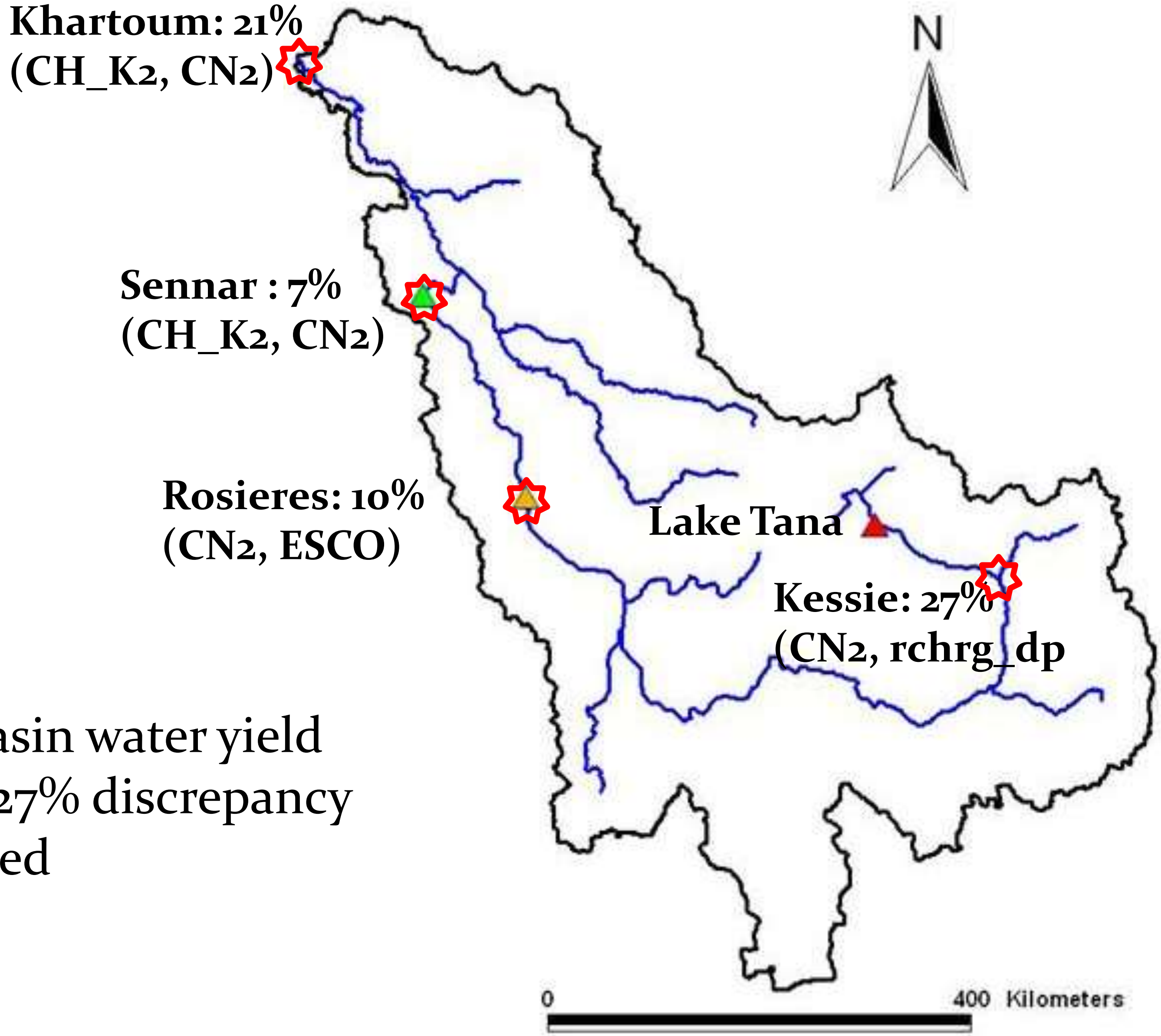
Methodology – Climate change scenarios

- Monthly relative change of precipitation and temperature relative to baseline period (1961-1990)
- Emission scenarios A2 (prevailing situation) and A1B (conflict free region)
- General Circulation Models: MIROC and INMCM
- Perturbation of baseline precipitation and temperature timeseries to represent future climate (2010-2039)
- Re-simulation of validated model using perturbed climatic data

Model Performance

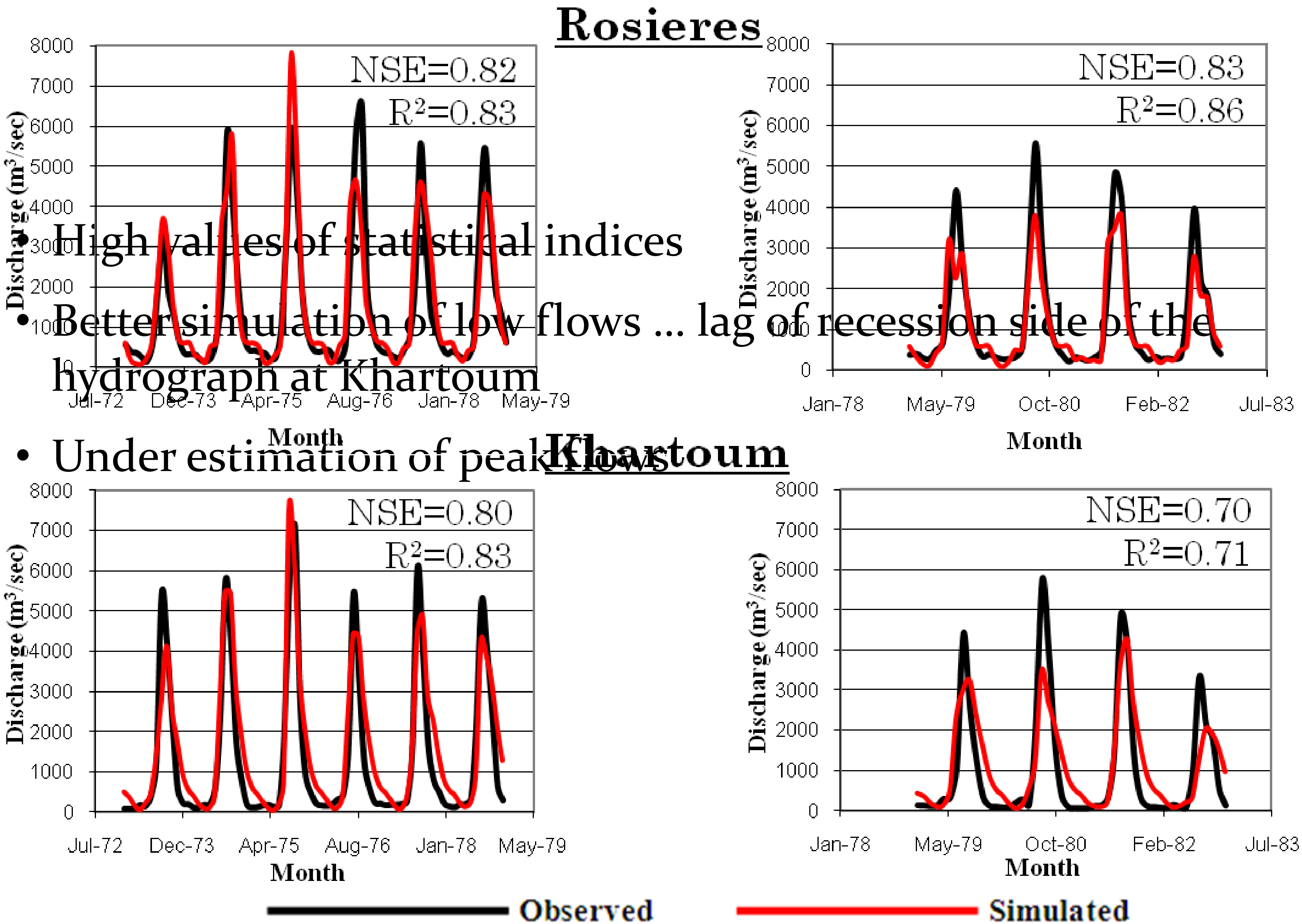
- Annual water yield of the entire river basin
- Graphical and statistical analysis of hydrograph
- Components of annual water balance
- Uncertainties on model output

Model Performance – Annual water yield



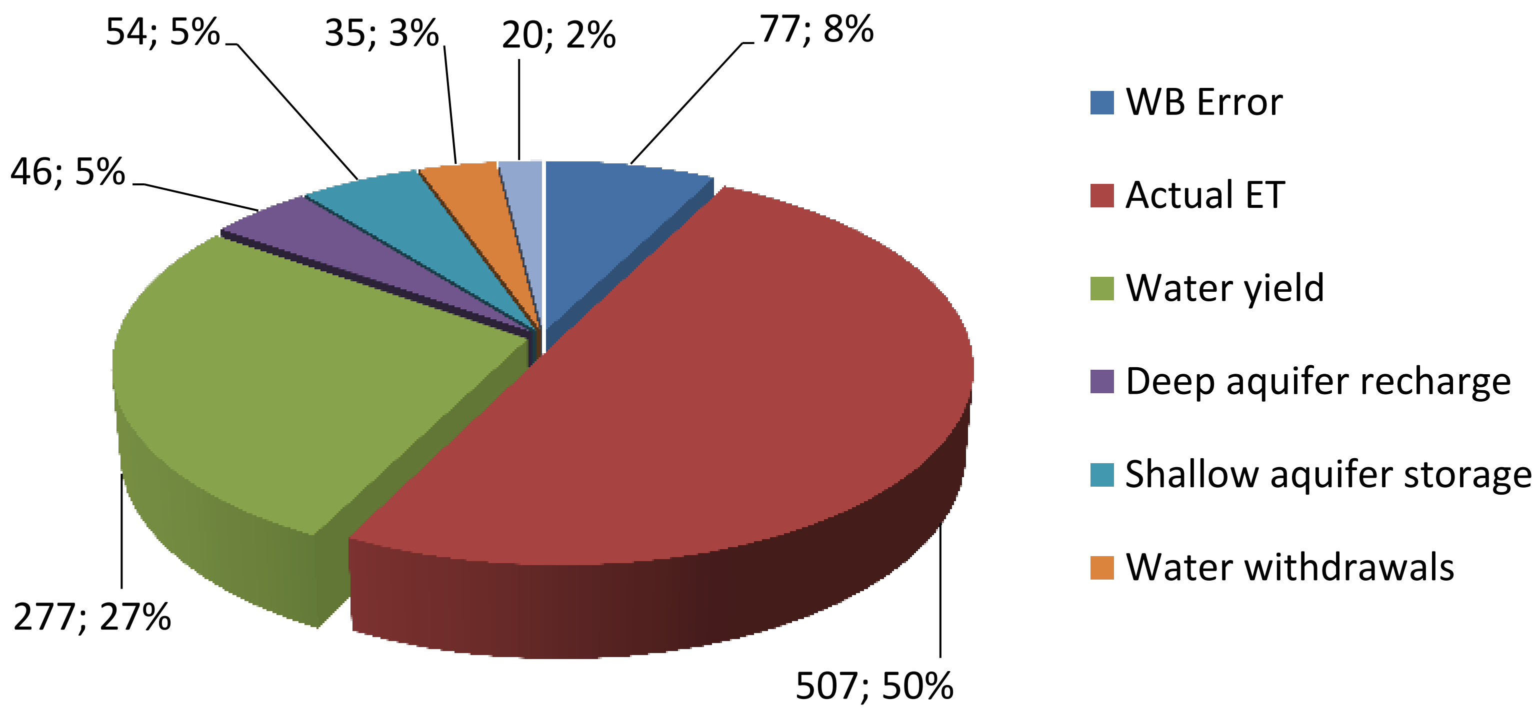
- Total basin water yield within 27% discrepancy simulated

Model Performance – Graphical and statistical indices



- High values of statistical indices
- Better simulation of low flows … lag of recession side of the hydrograph at Khartoum
- Under estimation of peak flows

Model Performance – Annual Water Balance

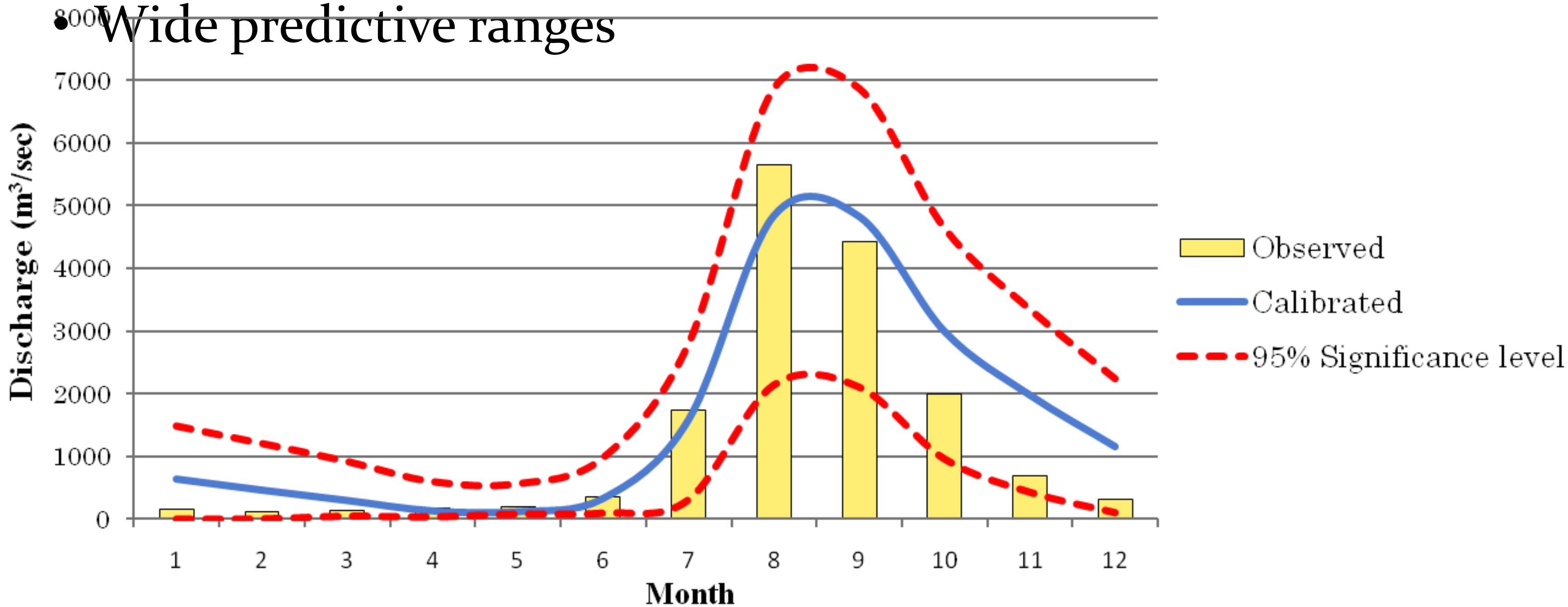


- Higher water yield and low actual ET
- WB closing error 8%

Model Performance – Predictive non-uniqueness

Station	Observed (mm)	Calibrated (mm)	Minimum prediction (mm)	Maximum prediction (mm)	% range
Kessie	678	615	418	916	-32 to 49
Rosieres	244	257	154	355	-40 to 38
Sennar	186	199	113	281	-43 to 41
Khartoum	136	165	73	238	-56 to 44

- Wide predictive ranges



Climate Change application

Average annual change in climatic variable and water yield by 2025

Emission Scenario	GCM	ΔP (%)	ΔT_{max} (ºC)	ΔT_{min} (ºC)	ΔPET (%)	ΔWYLD (%)
A2	MIROC	0	0.7	1.0	2	-11
	INMCM	5	0.8	2.2	1	2
A1B	MIROC	9	0.4	0.8	3	18
	INMCM	4	0.9	2.3	2	25

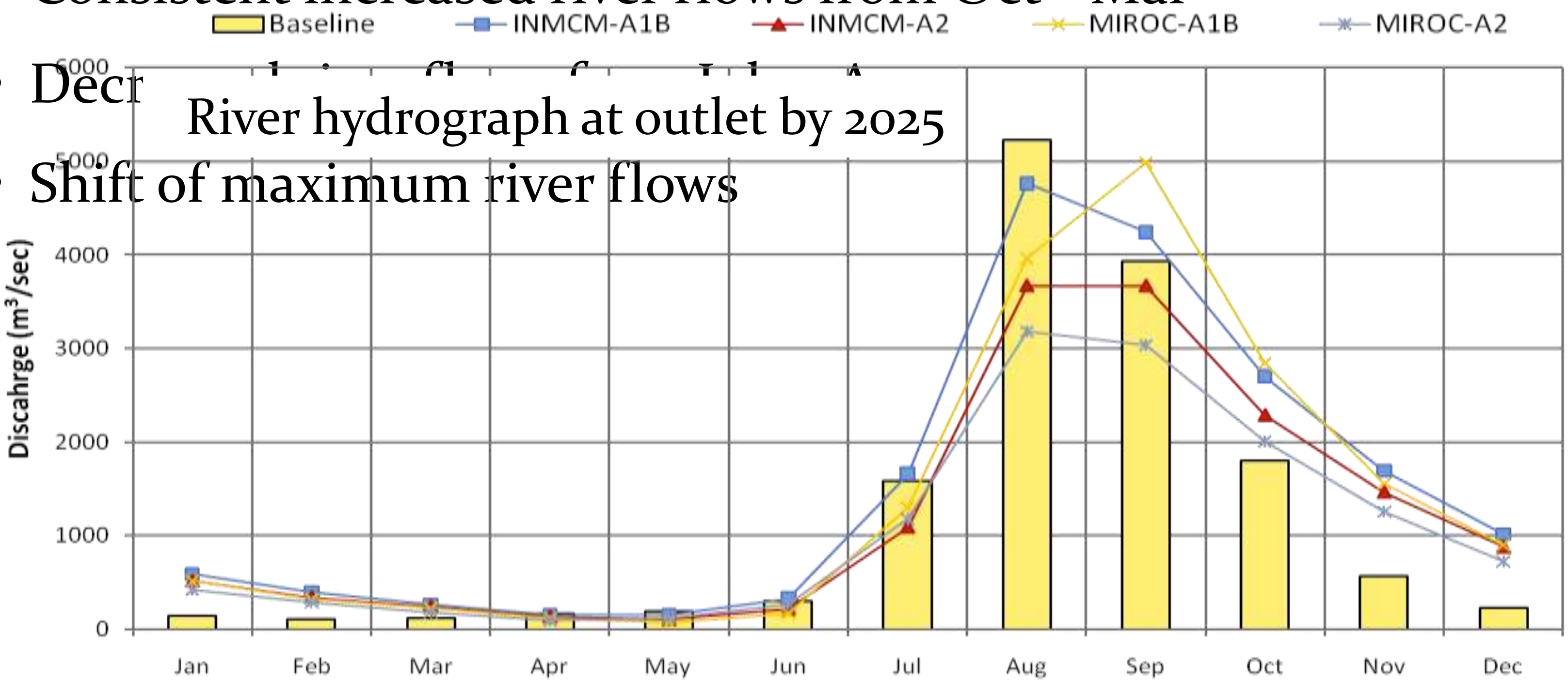
- MIROC presents cooler climate than INMCM
- Increase in annual water yield except MIROC–A2
- Consistent prediction for emission scenario A1B

Climate Change application

Seasonal water yield during low and high flows by 2025

Description	Baseline	MIROC		INMCM	
		A2	A1B	A2	A1B
Low flow water yield (mm)	9	11	12	13	16
High flow water yield (mm)	112	96	131	110	135

- Consistent increased river flows from Oct - Mar
- Decr
- Shift of maximum river flows



River hydrograph at outlet by 2025

Conclusions

- Fair model performance despite limited and non-homogenous data
- Capability of SWAT to simulate reservoir system and irrigation water withdrawals
- Wetter and warmer climate by the year 2025
- Increased low flows and decreased high flows
- Basin wide increase in annual water yield except MIROC-A2

Recommendation

- Optimization of outflow release rates and return flow fraction
- Use of direct and downscaled estimates of climatic variables from GCMs for climate change impact assessment
- Comparison of climate change impacts in upper and lower drainage areas of the river basin

THANKS