Hydrological system analysis and climate change modelling for the assessment of hydrological ESF/ESS in the Okavango River Basin

Jörg Helmschrot[1,5], Kralisch, S.[1], Quintino, M.[2], Mwewa, L.[3], Vushe, A.[3], Steudel, T.[1], Miguel, E.F.[2], Narciso, A.[2], Göhmann, H.[1], Flügel, W.-A. [1], **Weber, T.**[4], Hänsler, A.[4], Saeed, F.[4], Jacob, D.[4]

The Future Okavango (TFO)

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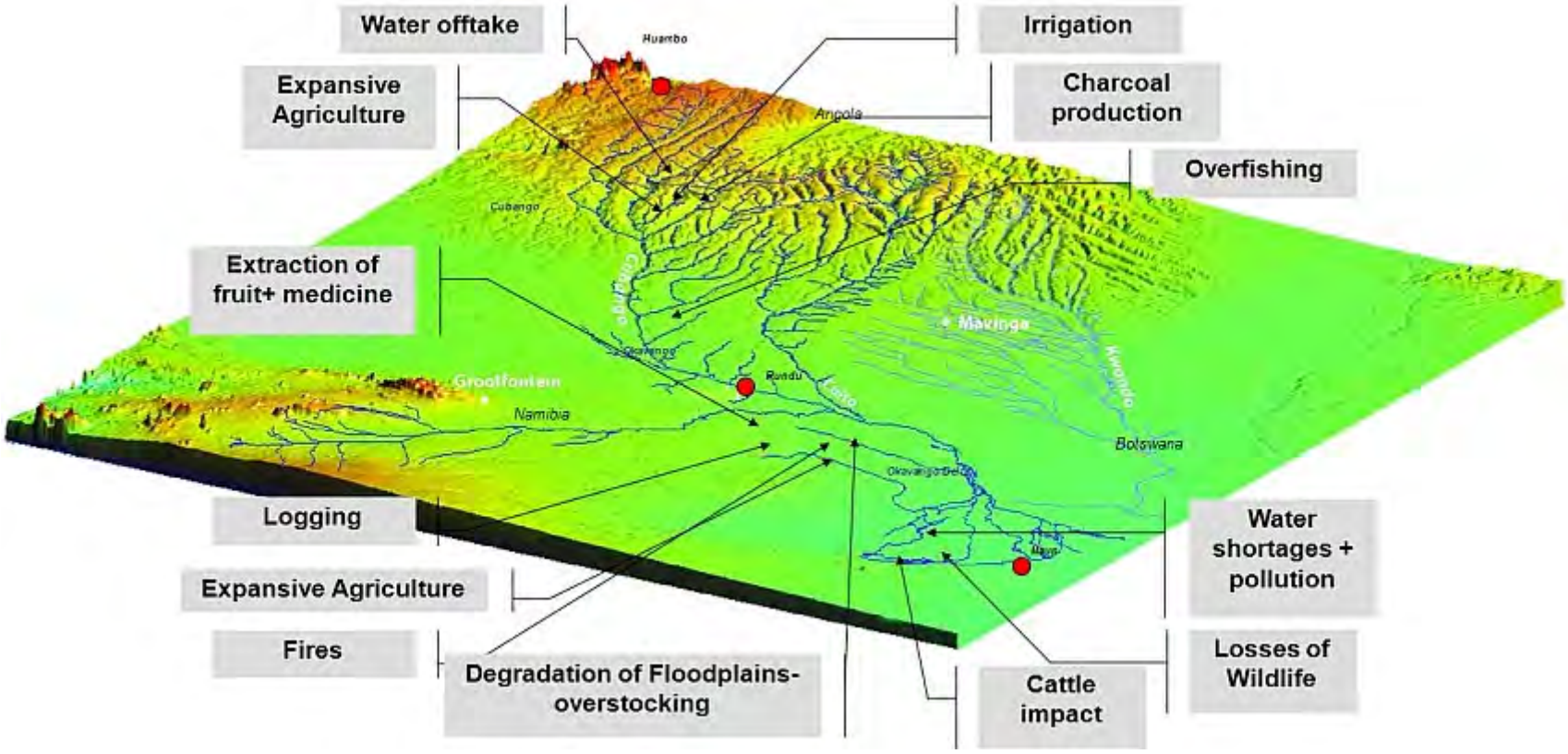
NACHHALTIGES LANDMANAGEMENT

The Future Okavango project

- Land use problems and ecosystem services in the Okavango Basin



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Okavango Basin

- high environmental diversity, but **sparse physio-geographic information** (soils, geology, LULC ...) and **hydro-met data** (no monitoring network)
- **little reliable knowledge** on socio-economic developments (refugees, population growth, water policy ...) and impacts (erosion, water budget ...)
- **political dimension** (conflict on water use, OKACOM)
- **no assessments** of land use and climate change impacts on water and other natural resources




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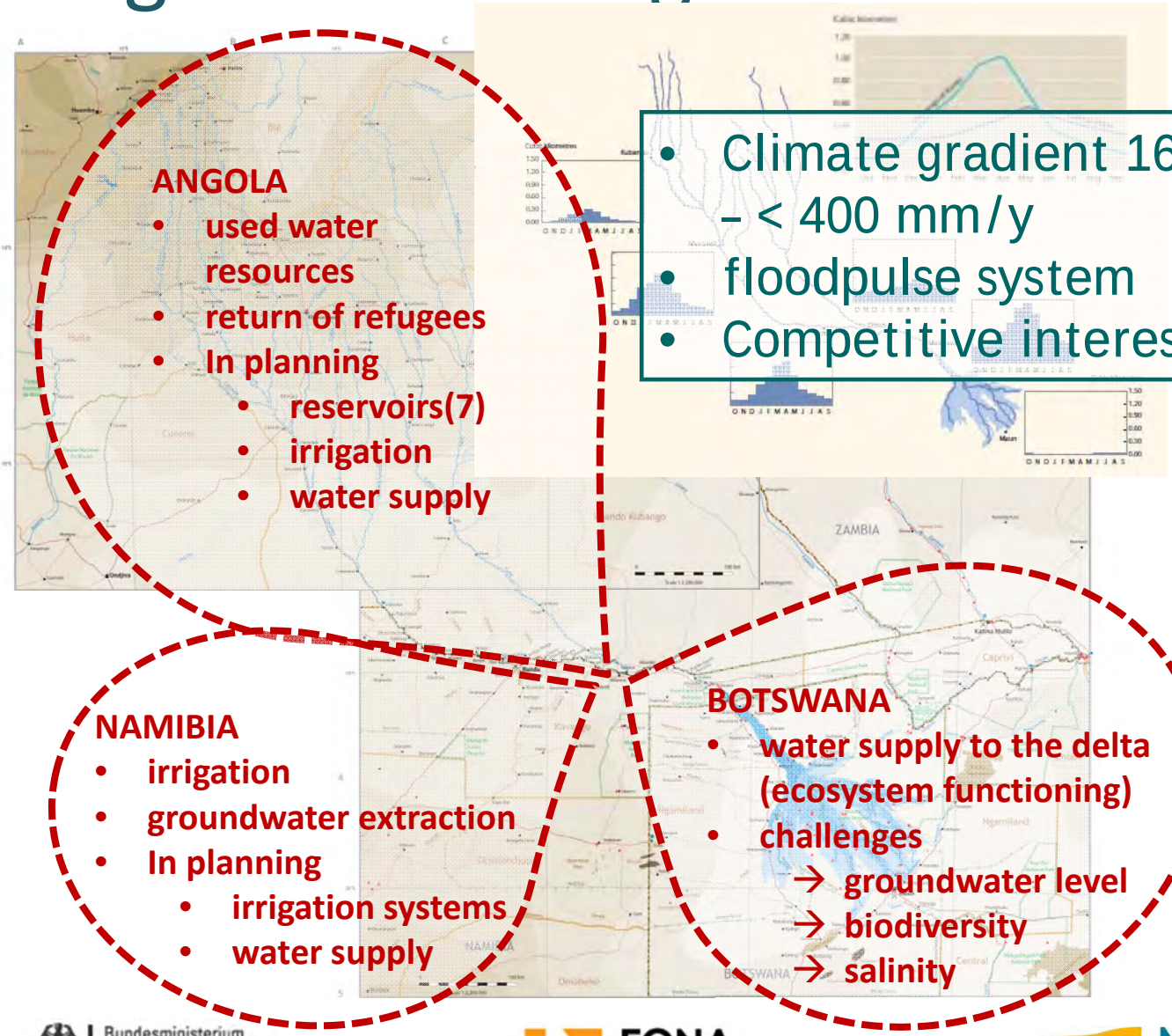
Regional challenges



ANGOLA
- used water resources
- return of refugees
- In planning
  - reservoirs(7)
  - irrigation
  - water supply

- Climate gradient 1600 – < 400 mm/y
- floodpulse system
- Competitive interests

NAMIBIA
- irrigation
- groundwater extraction
- In planning
  - irrigation systems
  - water supply

BOTSWANA
- water supply to the delta (ecosystem functioning)
- challenges
  - → groundwater level
  - → biodiversity
  - → salinity

RAINFALL

WATER DEMAND / USE

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Goals of SP01 and SP02

- providing of **high resolution climate change information** (including uncertainty estimates, data providing, sensitivity tests, etc.)
- better understanding of **scale-related interactions between land management, climate conditions and hydrological ESF/S**
- develop and implement robust methods and tools for an **integrated assessment of land management options and CC impacts on hydrological ESF/S** at local, regional and trans-regional level

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Climate: Re-Analysis and projections

- Dynamical Downscaling

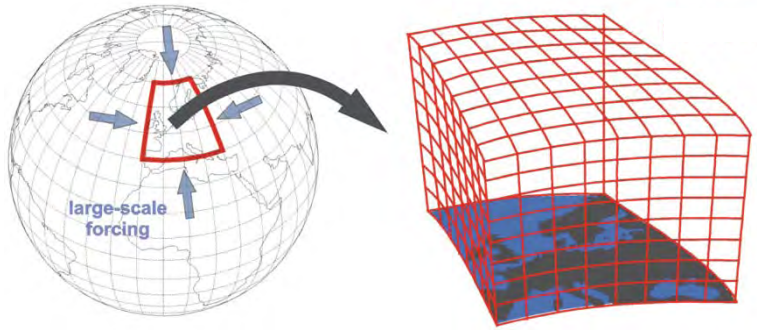
General Circulation Model (GCM)

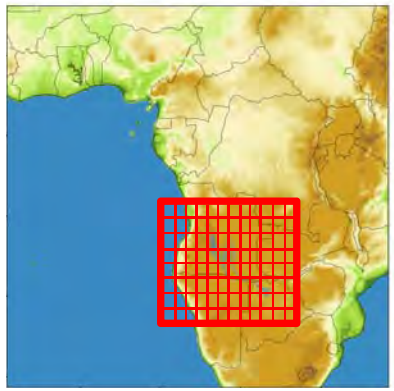
e.g. ECHAM, EC-Earth

Regional Climate Model (RCM)

e.g. REMO, WRF

Okavango Model Domain



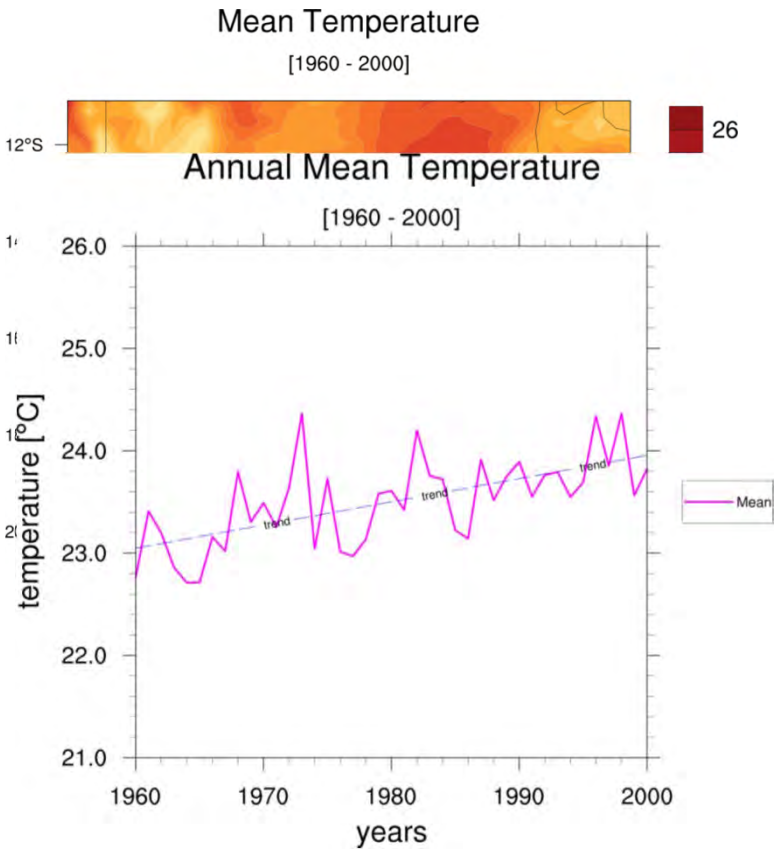


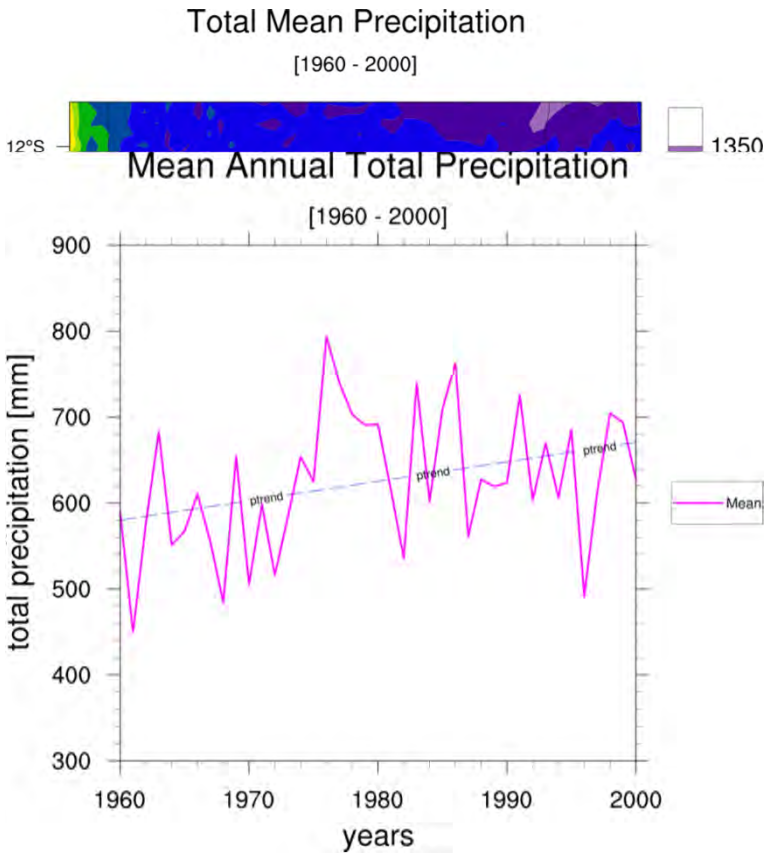
horiz. res. approx. 310 km (equator)
31 vertical level

horiz. res. 0.22 ° x 0.22 ° (25 x 25 km²)
27 vertical level

Climate re-analysis

- Increasing temperature and rainfall (ERA 40, 1960-2000)





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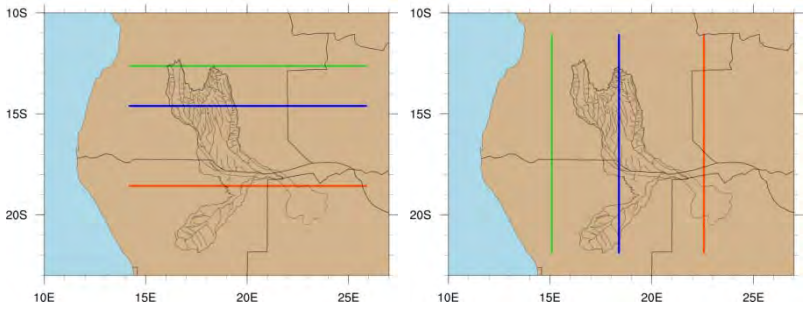
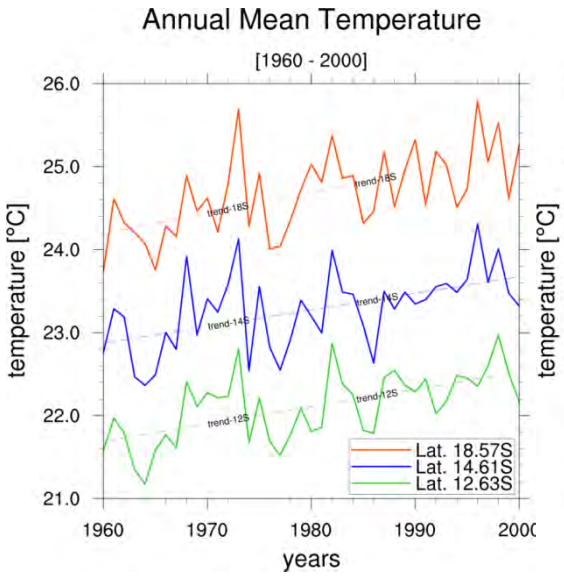
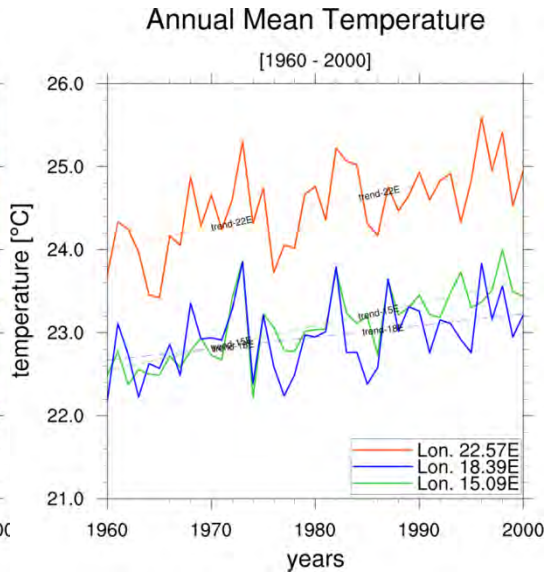
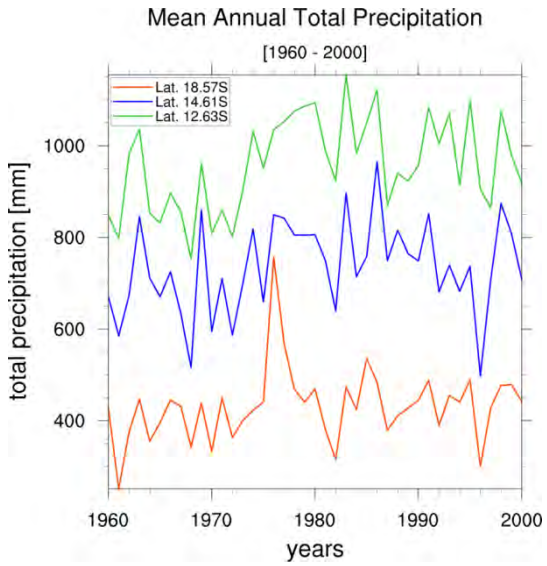
Climate re-analysis

- Hydroclimatic gradients









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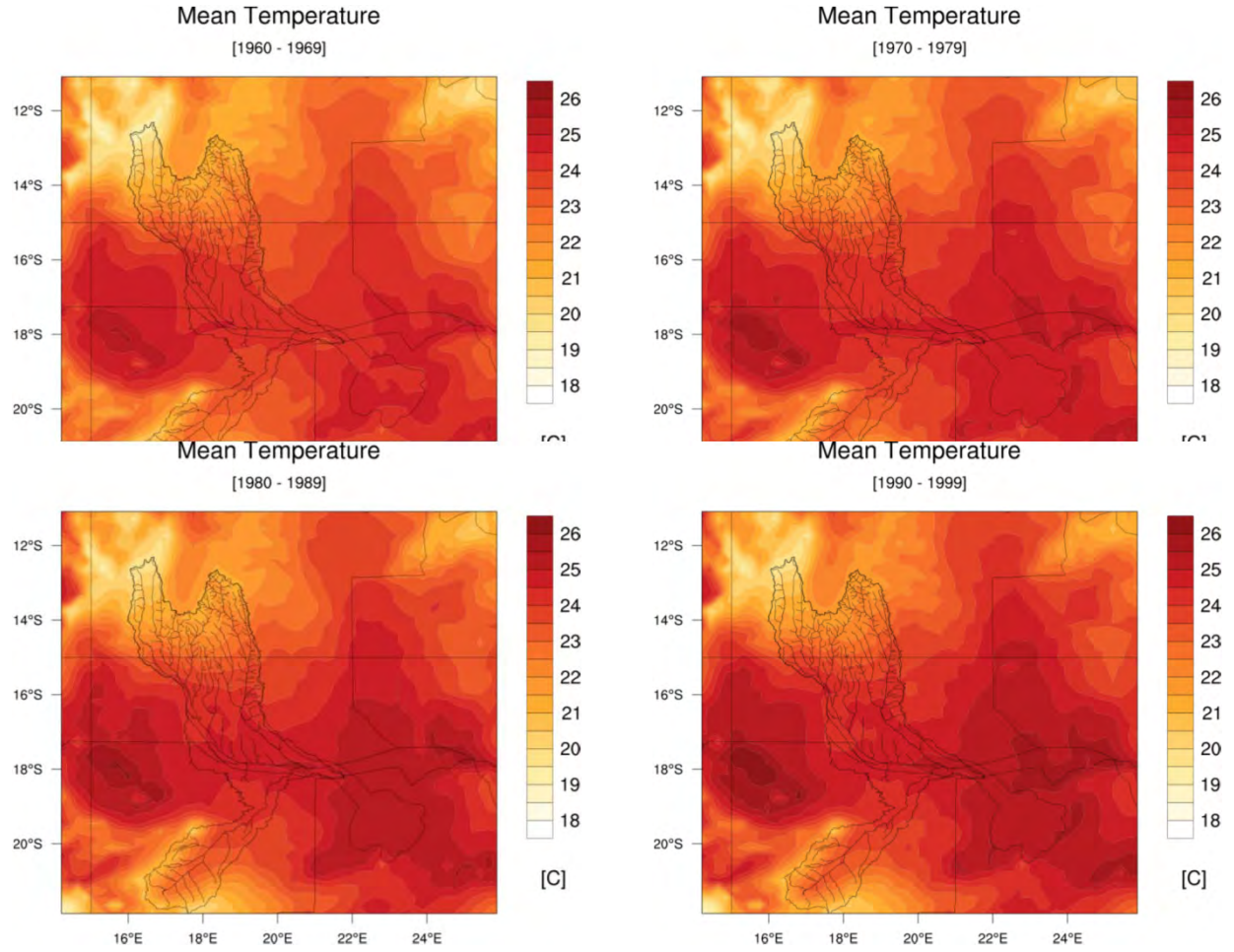
Climate re-analysis

- Temperature (10-years means)



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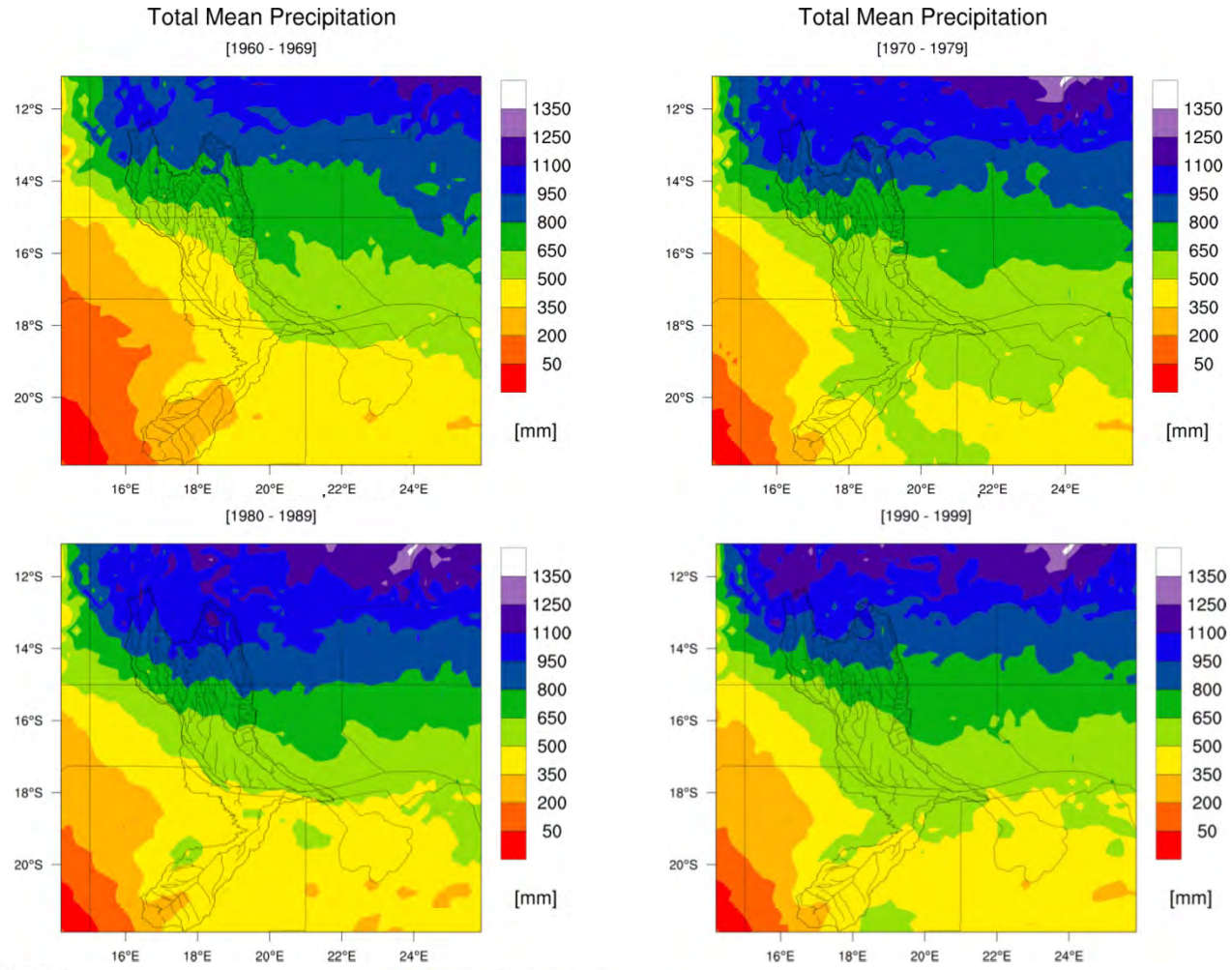
Climate re-analysis

- Precipitation (10-years means)



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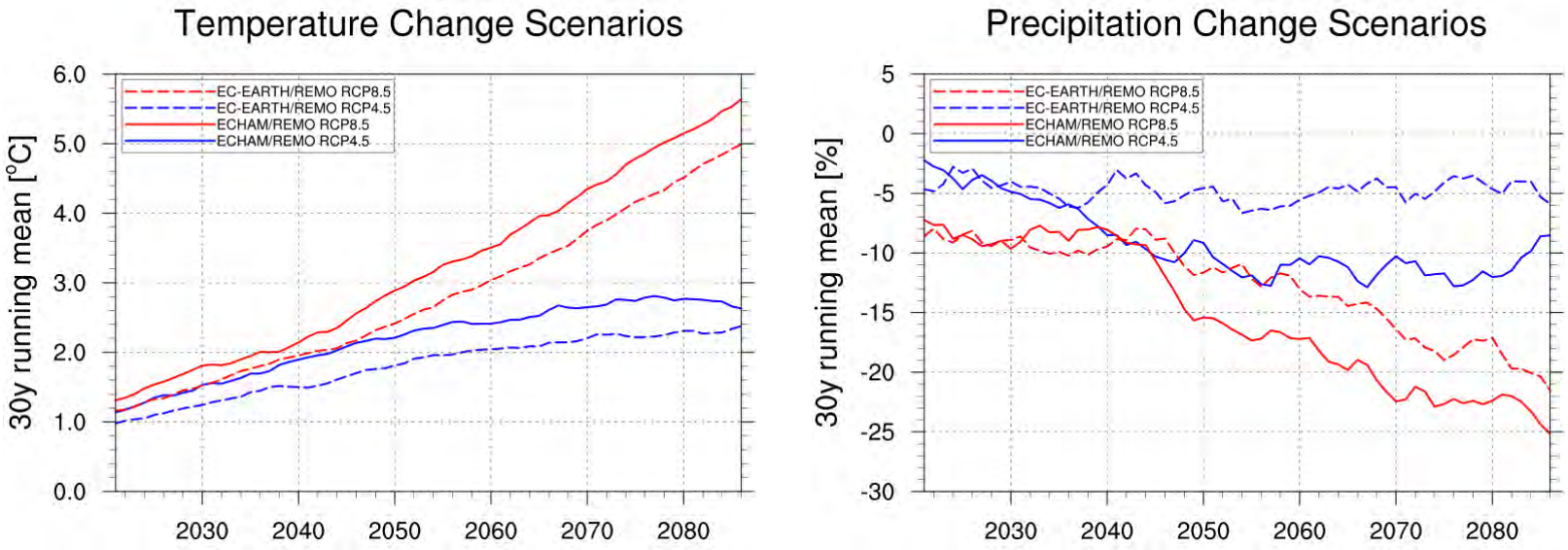
Climate (projections)

- Projected climate change in the Okavango basin

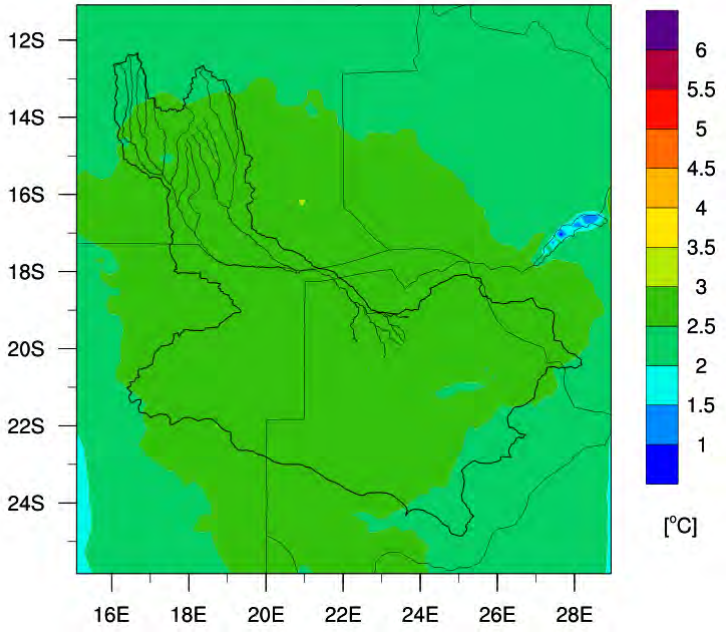


Reference period 1971-2000

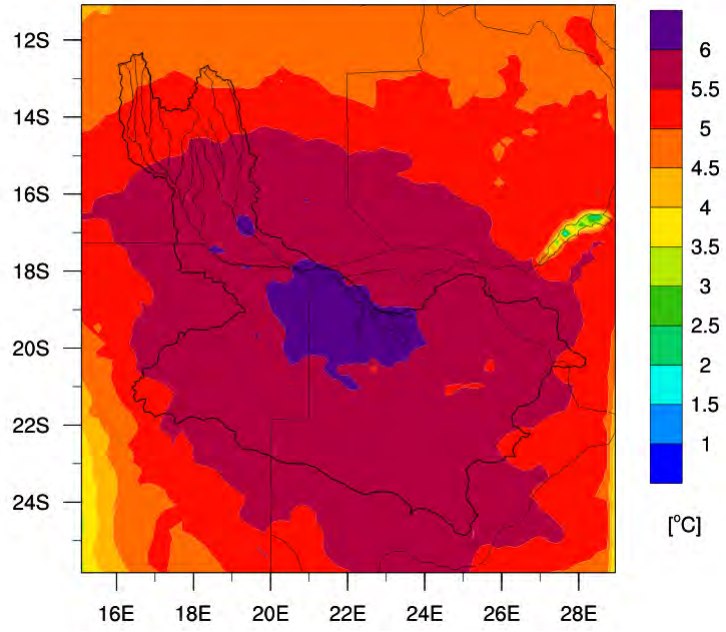
Climate (projections)

- Projected 2m Temperature Change (2071-2100)

Annual Mean, ECHAM/REMO, RCP4.5



Annual Mean, ECHAM/REMO, RCP8.5

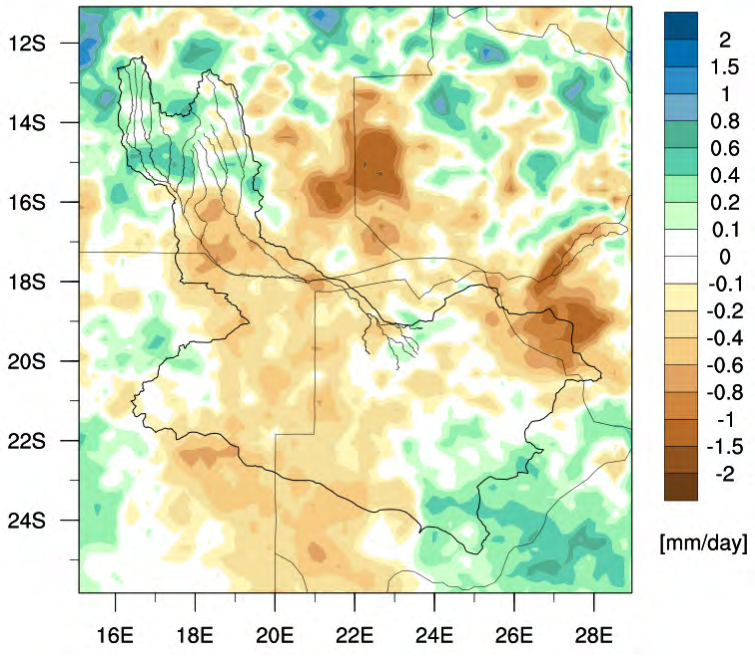


Reference period 1971-2000

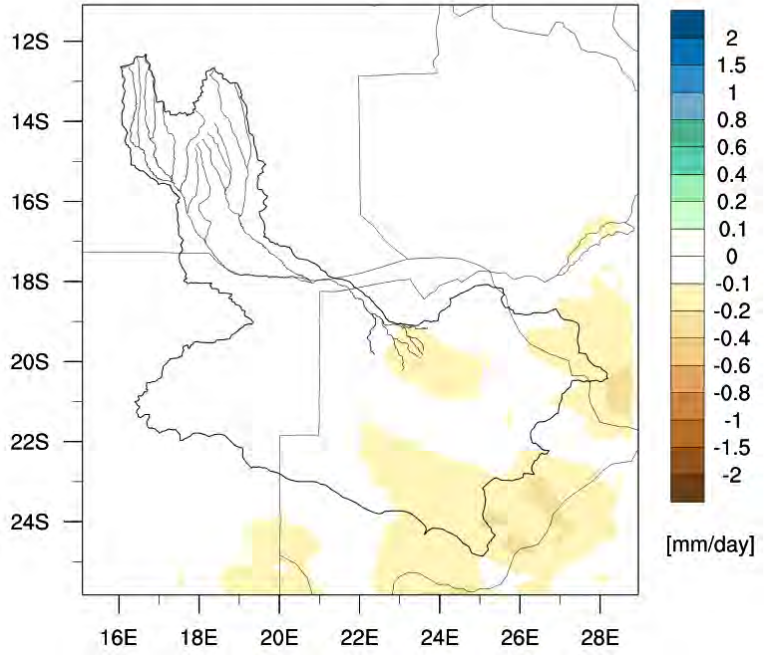
Climate (projections)

- Projected Precipitation Change (2071-2100)

DJF, ECHAM/REMO, RCP4.5

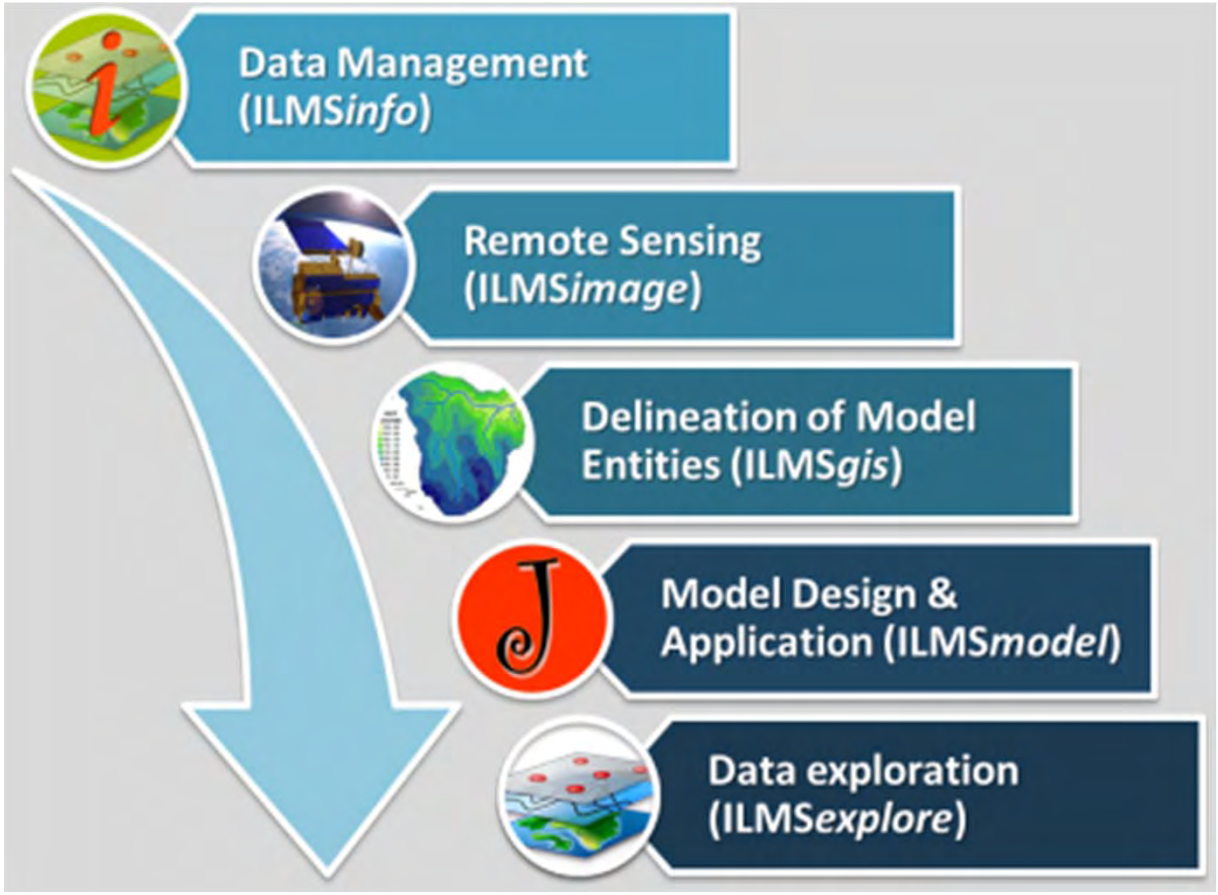


JJA, ECHAM/REMO, RCP4.5



Reference period 1971-2000

Model Toolbox (ILMS)



More information: ***ilms**.uni-**jena**.de*

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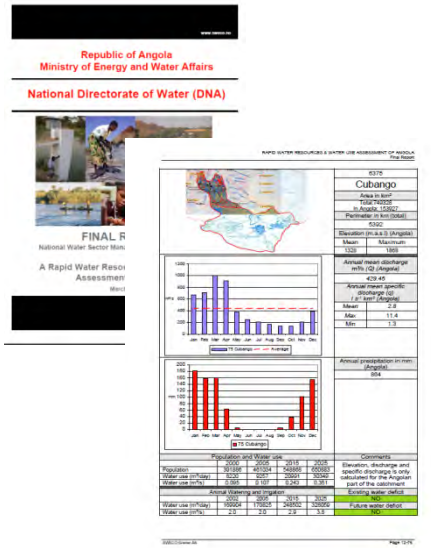
Hydrological Modelling: Data base

- Hydro-met data (DNRH, local authorities, NamWater, Rural Water Supply, Farmers, INAMET)
- farmer interviews (irrigation water use, fertilizer use, land management, irrigation techniques …)



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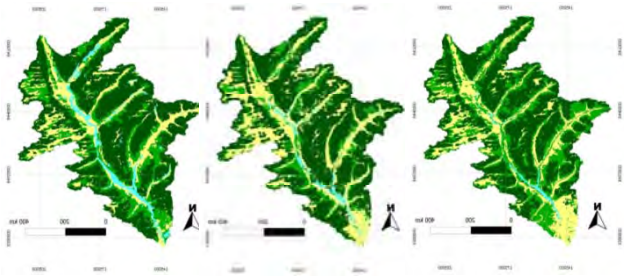
Hydrological Modelling: Data base

- Re-installation of 6 runoff stations in Angola (2012/13)
- information on soil variety (N-S-gradient), vegetation structure (N-S-gradient), relief dynamic (GPS), land cover and change (EO-data)



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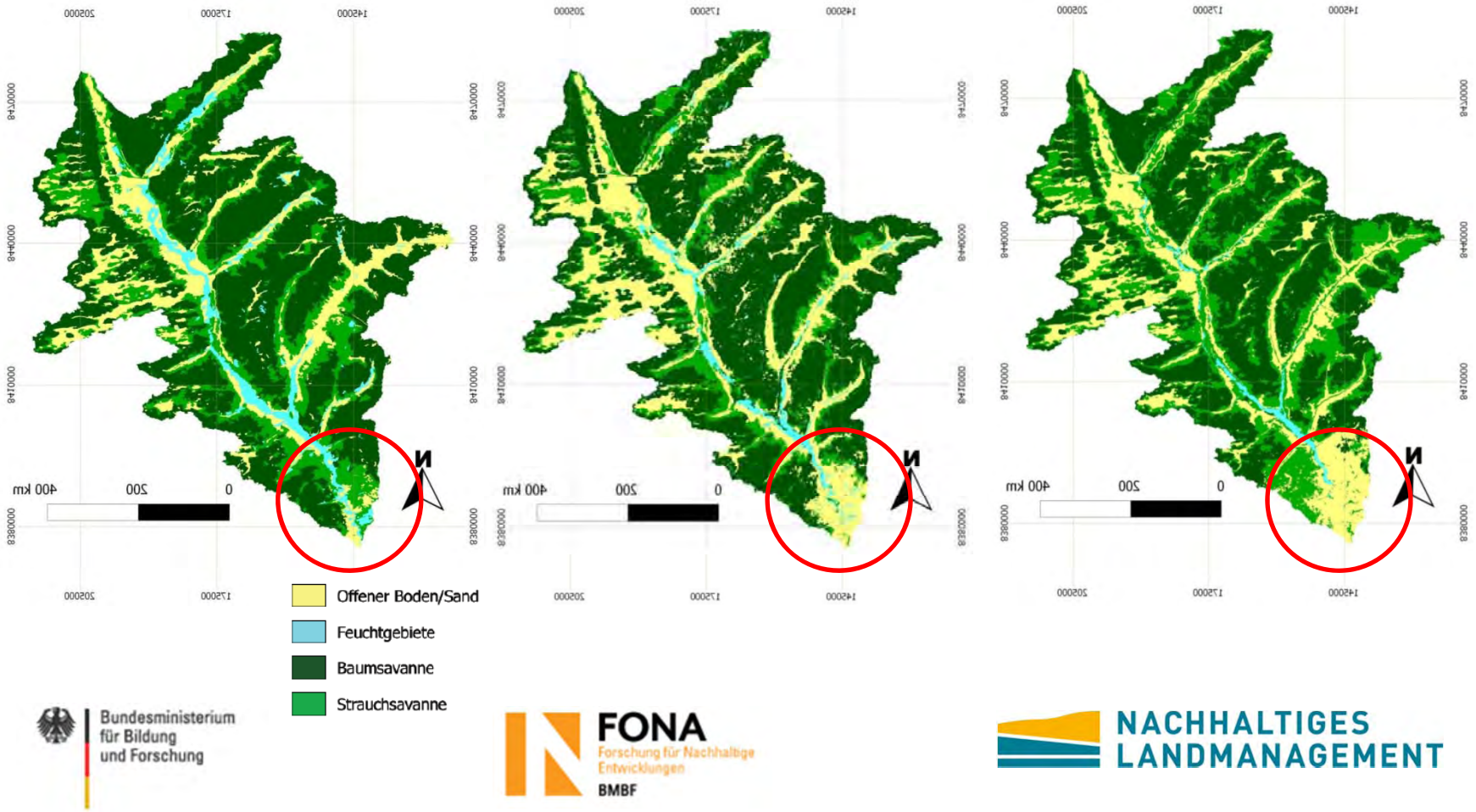
System analysis

- Analysis of land management changes (EO-based, field work) → e.g. significant degradation in the surroundings of expanding cities (e.g. Menongue)
- Analysis of time series → spatial pattern, temporal dynamics
- Analysis of soil, vegetation and relief dynamics (HRUs)
- Water use estimates (Kavango region)

System analysis

- Land use / change dynamics (EO-based)

1970 2000 2010



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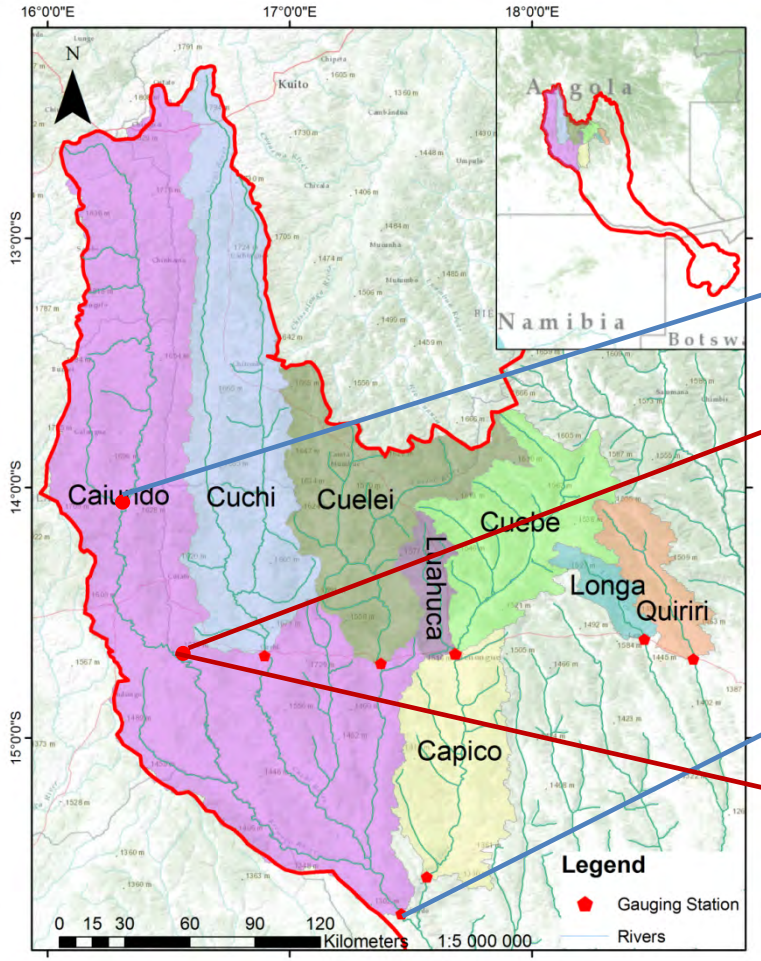
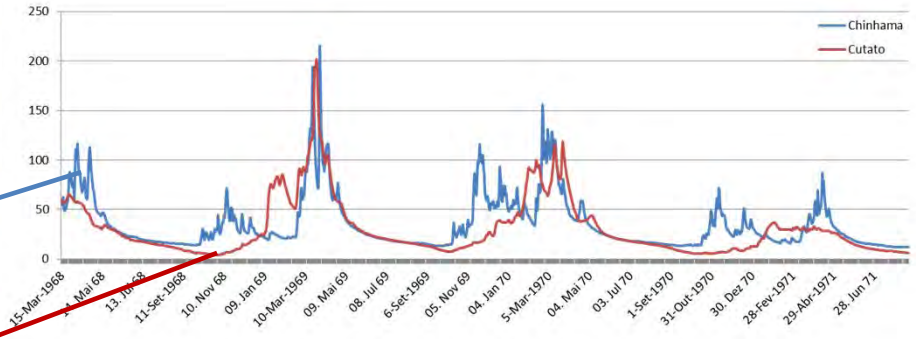
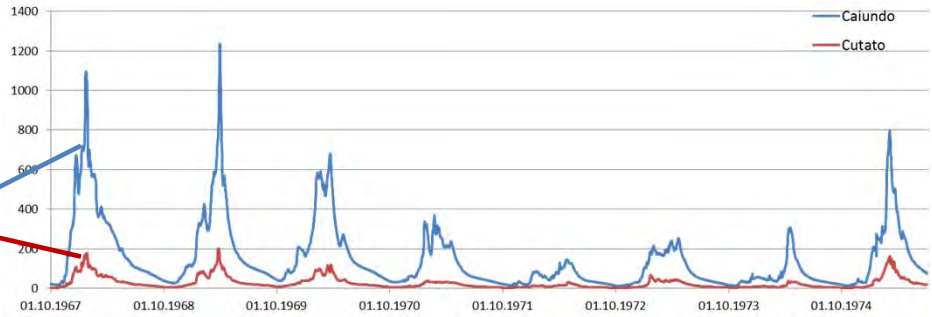
System analysis







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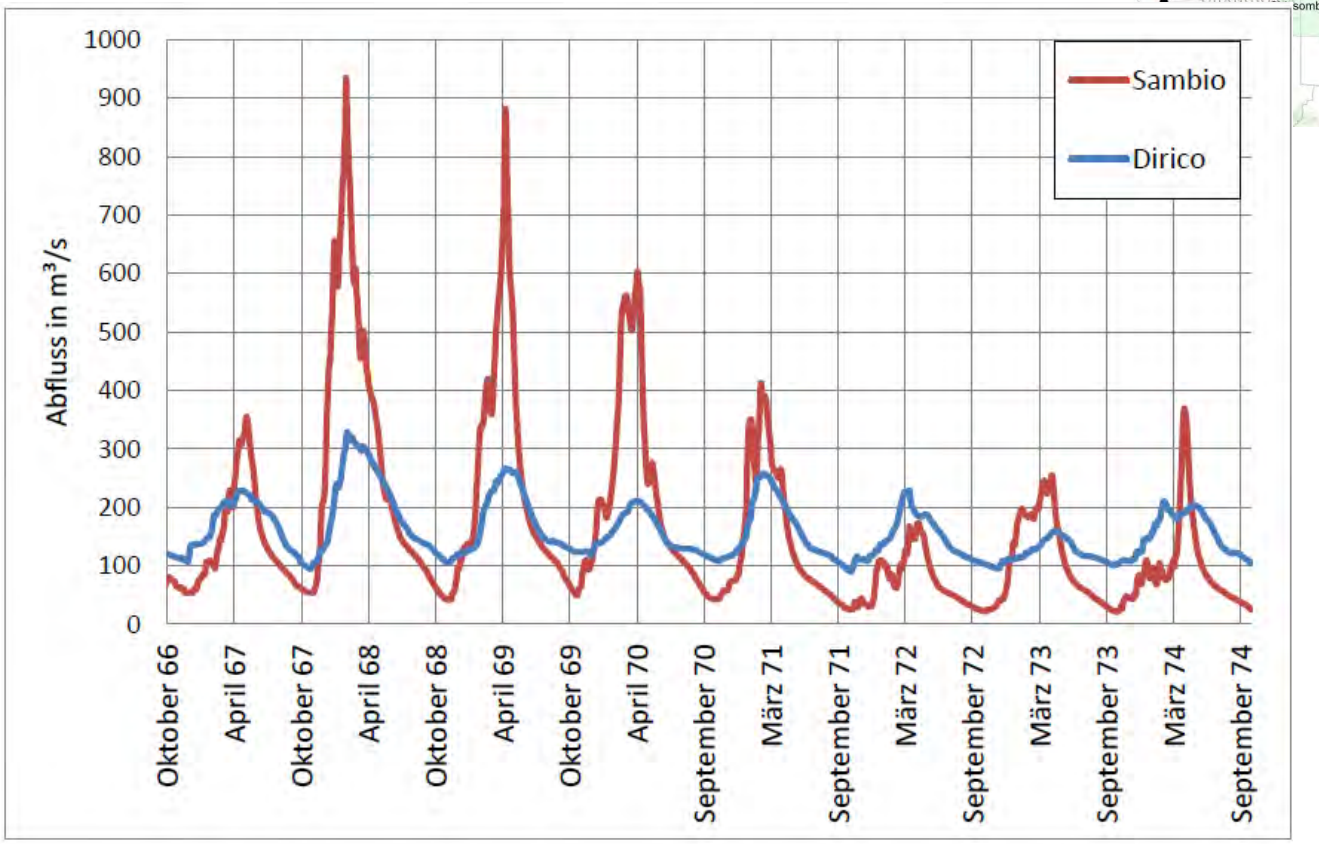
Runoff dynamics

- Runoff generation processes



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Runoff dynamics

- Runoff reduction between 1958 and 1995 (based on daily data)

	Mukwe (Okavango)	Rundu (Cubango)	Dirico (Cuito)
Täglich	-32%	-27%	-25%
MHQ	-30%	-34%	-28%
MNQ	-30%	-31%	-28%
Oktober	-21%	-15%	-19%
April	-27%	-32%	-24%

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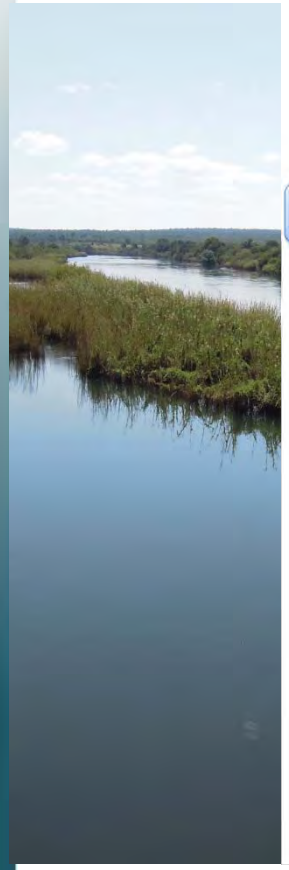
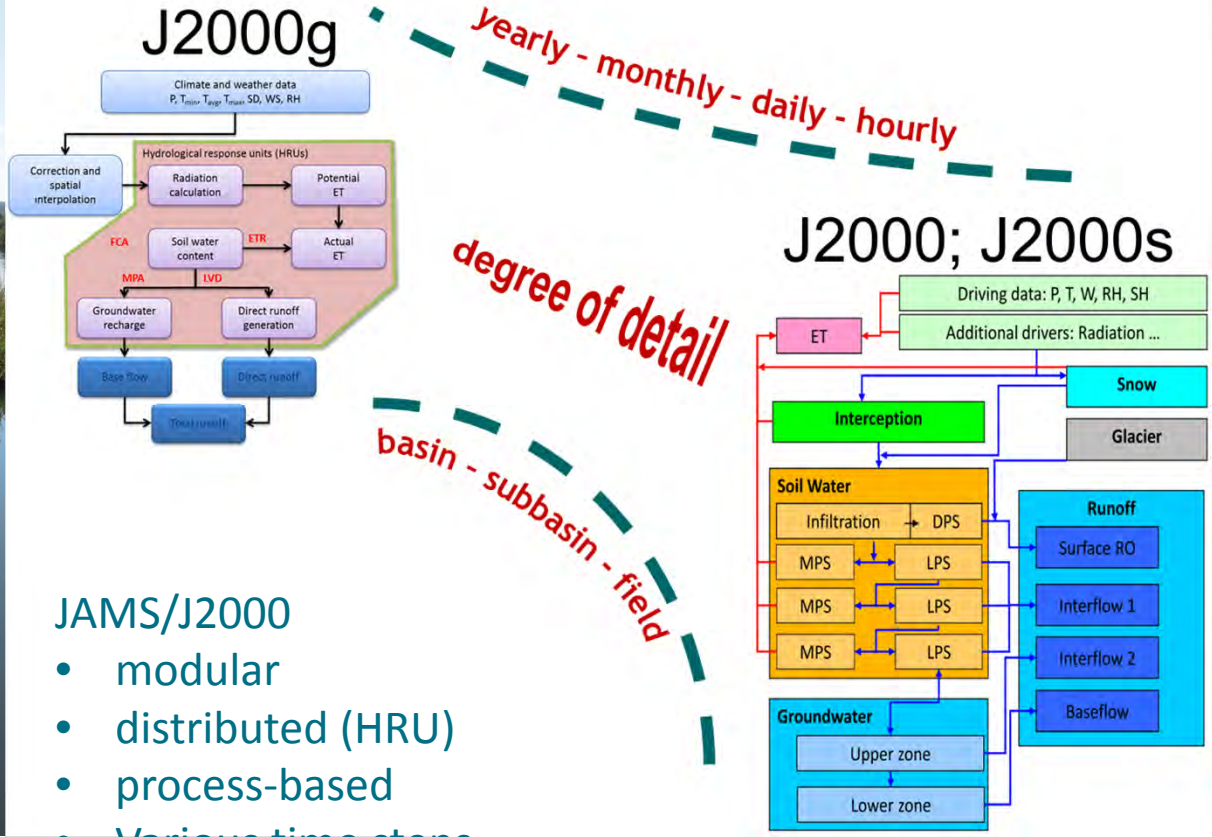
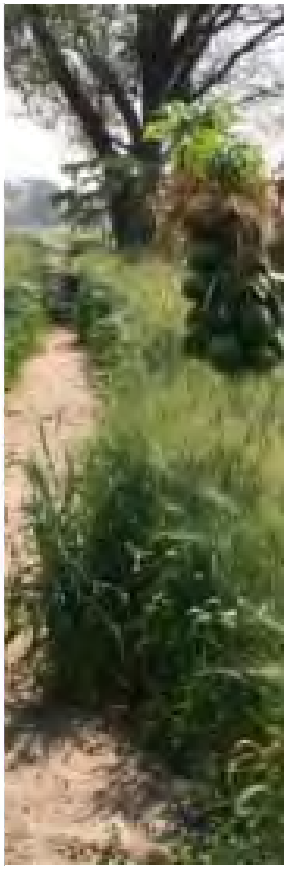
Model approach (ILMS)

- Up- and Downscaling







JAMS/J2000

- modular
- distributed (HRU)
- process-based
- Various time steps

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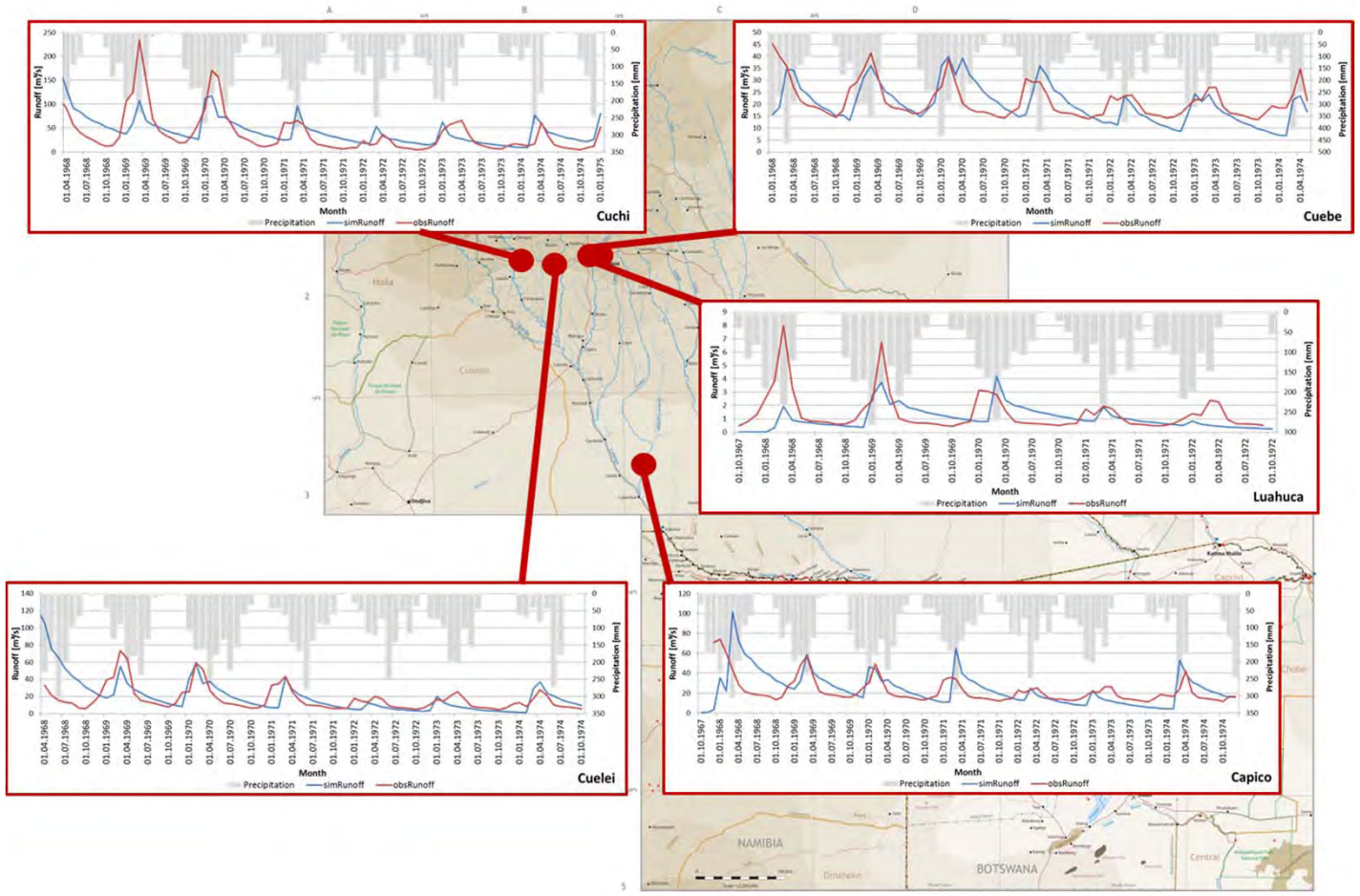
Runoff modelling

- Monthly models for all sub-basins (ongoing)



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Summary

- **Climate dynamics**
  - 1960 – 2000: Increasing temp and rainfall, but high spatial variability
  - 2071 – 2100: all scenarios show temperature increases, weaker signals for rainfall
  - Input variables for hydrological models from climate models and historical/actual records
- **System analysis (hydrological dynamics, land management, water use)**
  - Land management change around cities
  - Actual water use does not impact runoff volumes
  - Information about spatio-temporal pattern of Hydrodynamics
- **First monthly models (ongoing)**

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Outlook

- **SP01:** Transregional moisture transport analysis (Dec 2013)
- **SP01/02:** Spatial analysis (July 2013)
- **SP02:** Daily models for six subbasins (June 2013 - ongoing)
- **SP02:** Monthly models for the Cubango and Cuito subbasins, and for the Okavango at Mohembo weir (July/August 2013)
- **SP01/02:** Land use and CC impacts (December 2013 - ongoing)
- **SP01:** Model coupling→ Basin (FSUJ) & Delta (ORI)(2014/15)
- **SP01:** Irrigation efficiencies (2014/15)

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THANK YOU!

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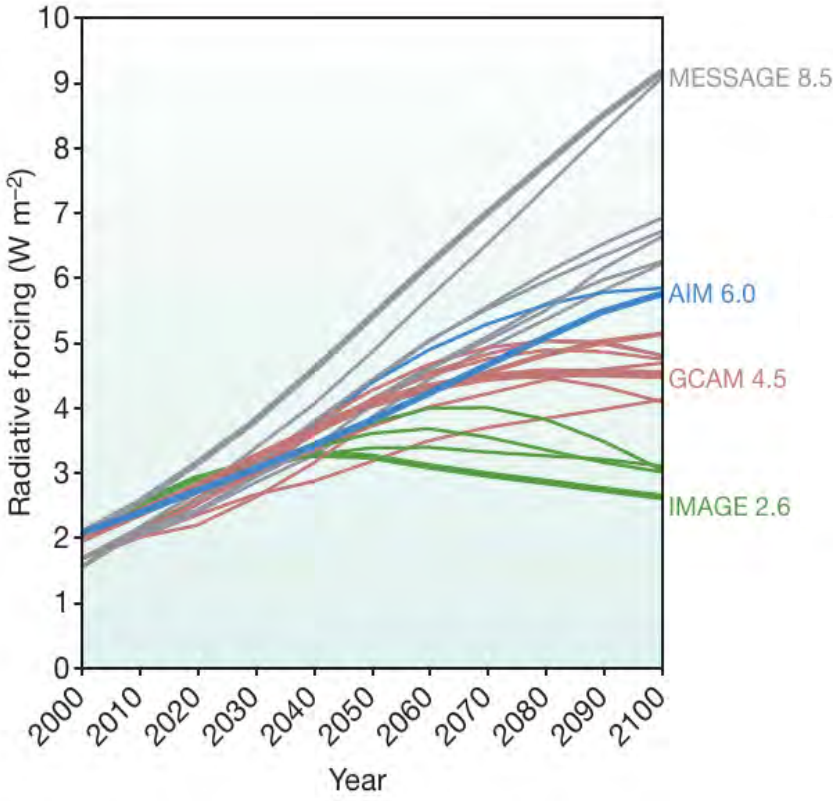
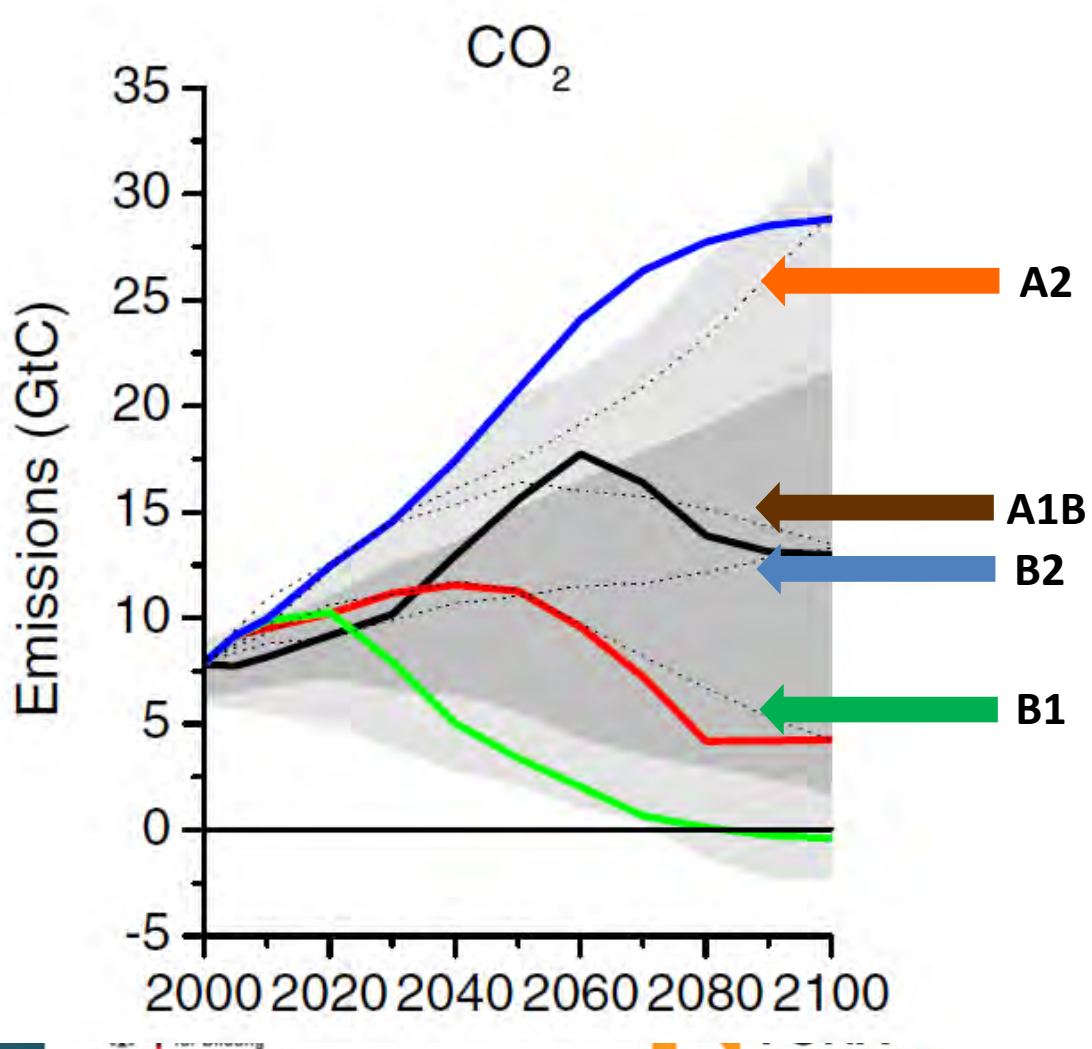
Next Generation Scenarios for Climate Change Assessment

- RCP8.5
  - >8.5 W/m² in 2100
- RCP6.0
  - ~6 W/m² at stabilization after 2100
- RCP4.5
  - ~4.5 W/m² at stabilization after 2100
- RCP 2.6
  - Peak at ~3 W/m² before 2100 and then declines



Moss et al., 2010

RCPs versus SRES Scenarios



Changed after Van Vuuren DP, Edmonds J, Thomson A, Riahi K, Kainuma M, Matsui T, Hurtt GC, Lamarque J-F, Meinshausen M, Smith S et al.: Representative concentration pathways: an overview. Climatic Change, 109, 5-31, 2011.