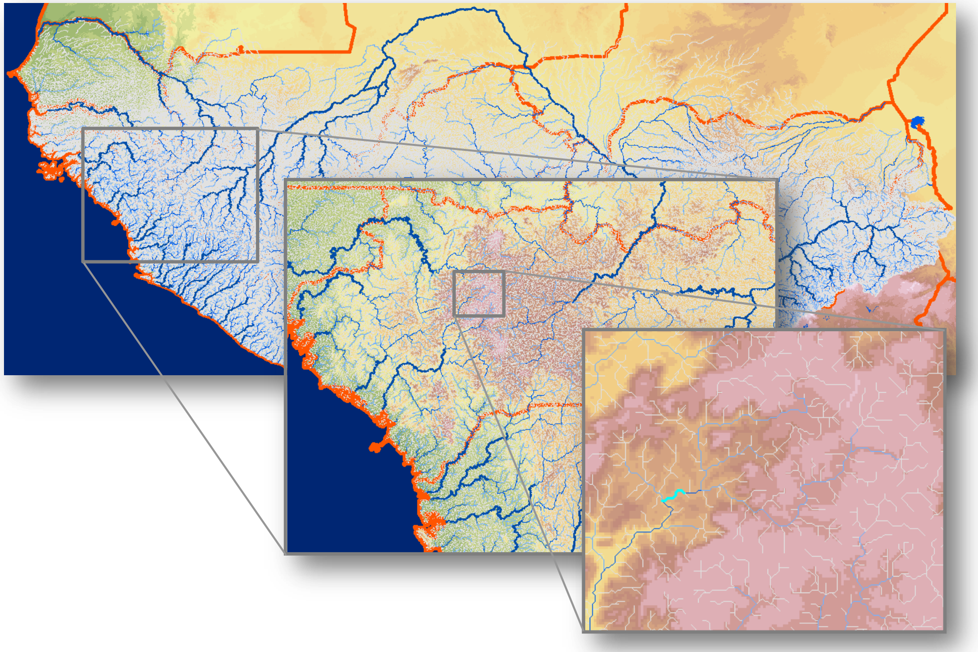
GIS Hydropower Resources Mapping for ECOWAS Region

Session 4: Climate change projections



Training, Dakar, Senegal, July 2016

Trainer: Harald Kling

Pöyry, Hydro Consulting, Hydropower, Austria

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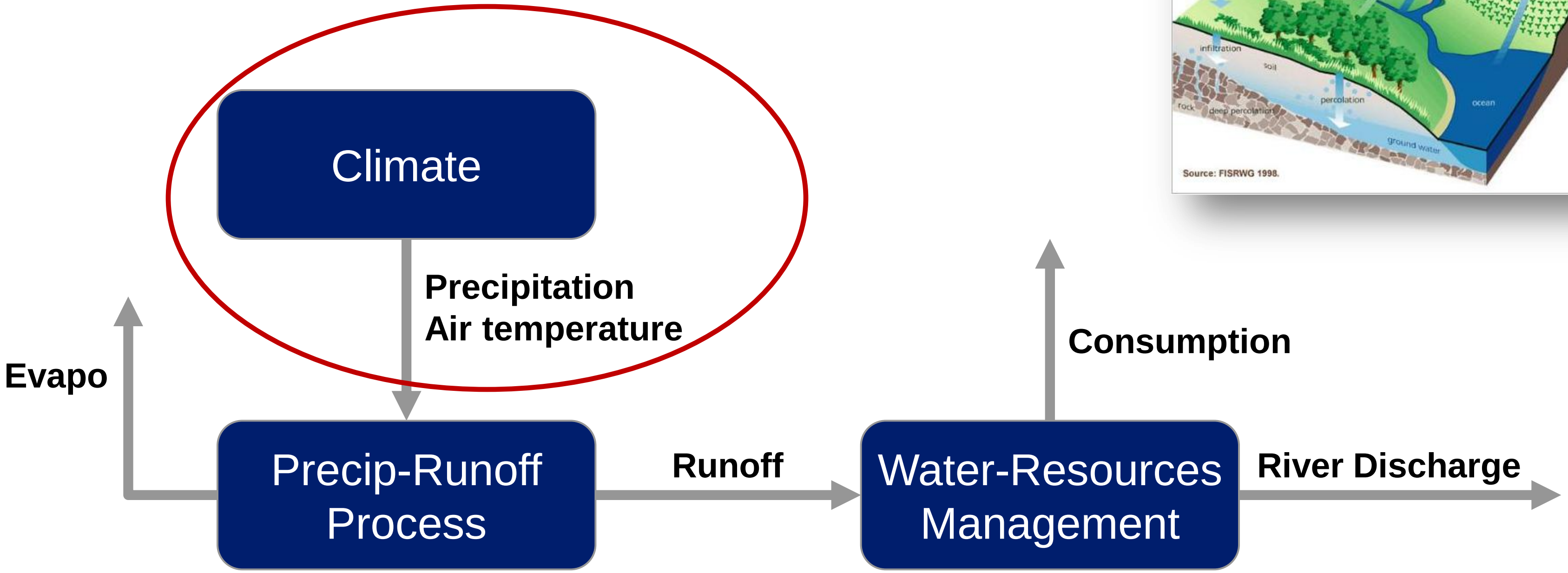
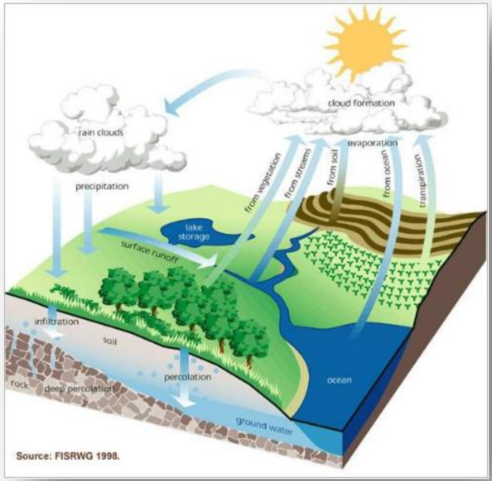
Water balance theory

Main drivers for water availability





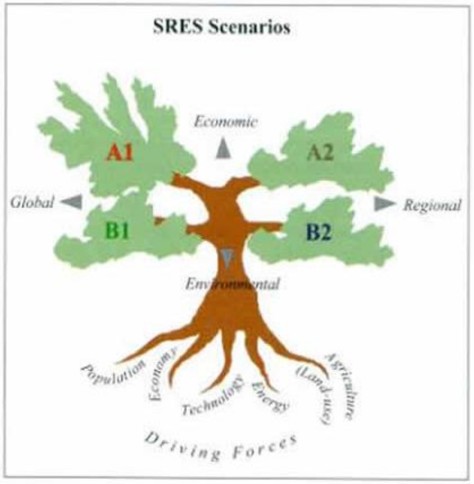
What are the climate change projections for West African basins?

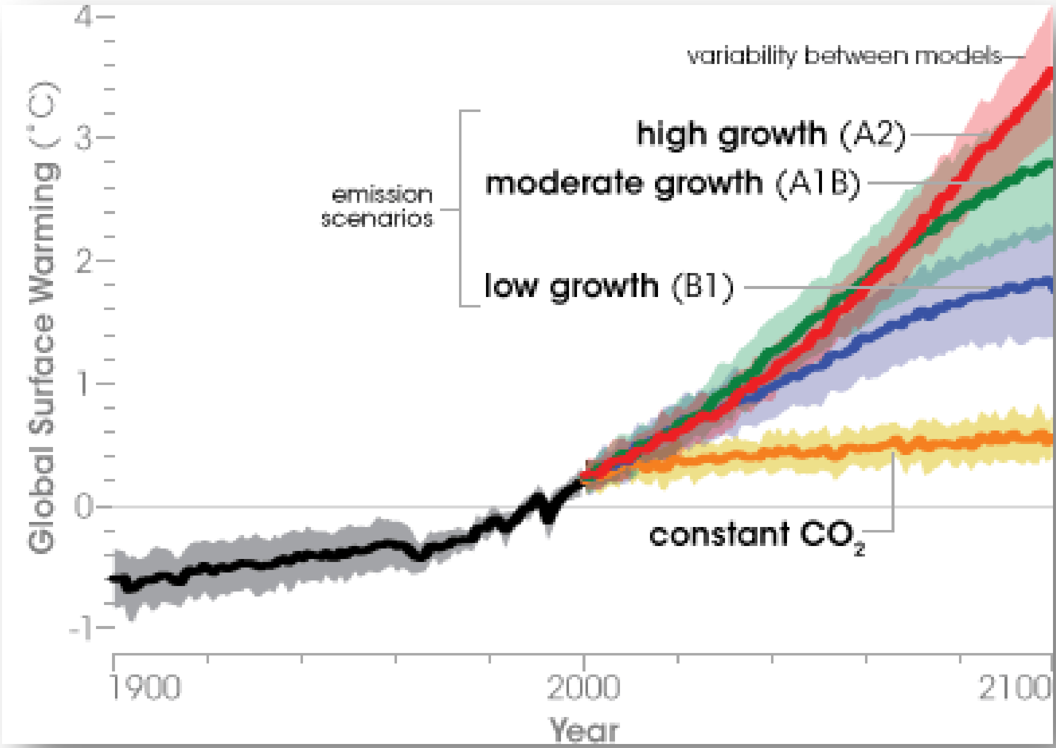
- Projected future air temperature?
- Projected future preciptiation?
- Impacts on discharge and hydropower?

Emission scenarios of IPCC

4th Assessment Report (2007):

SRES scenarios

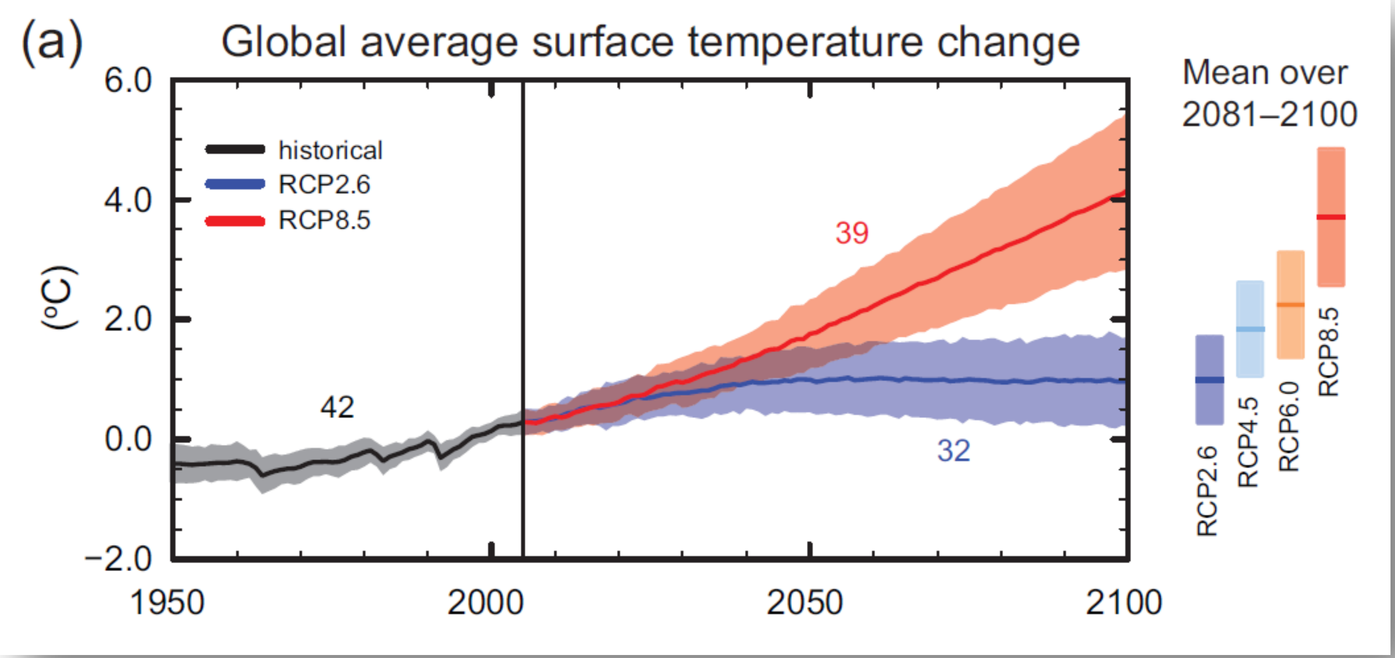




Emission scenarios of IPCC

Fifth Assessment Report (2013):

Representative Concentration Pathways (RCP)

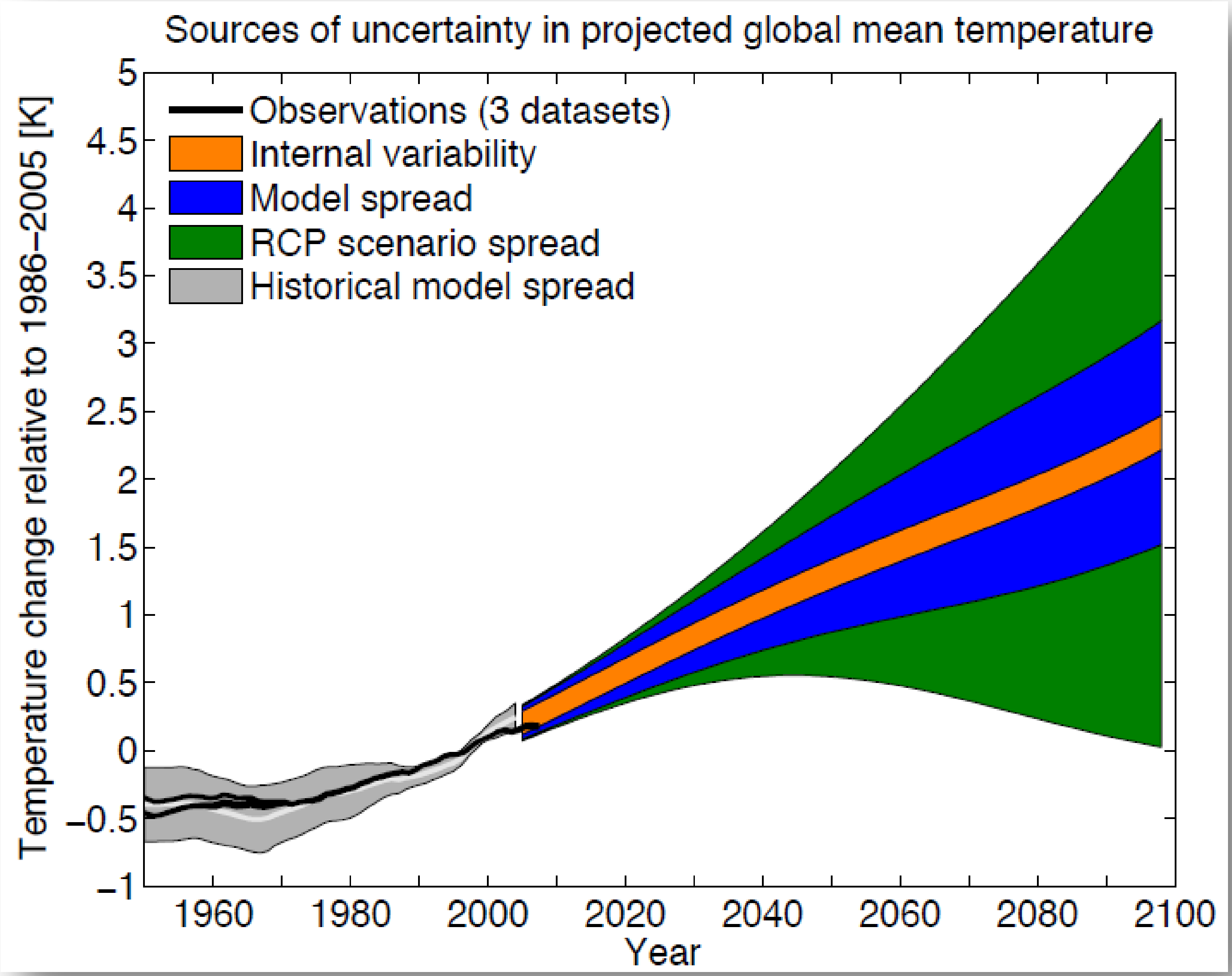


RCP2.6: very low emissions (unrealistic)

RCP4.5 & RCP6.0: stabilization scenarios (optimistic)

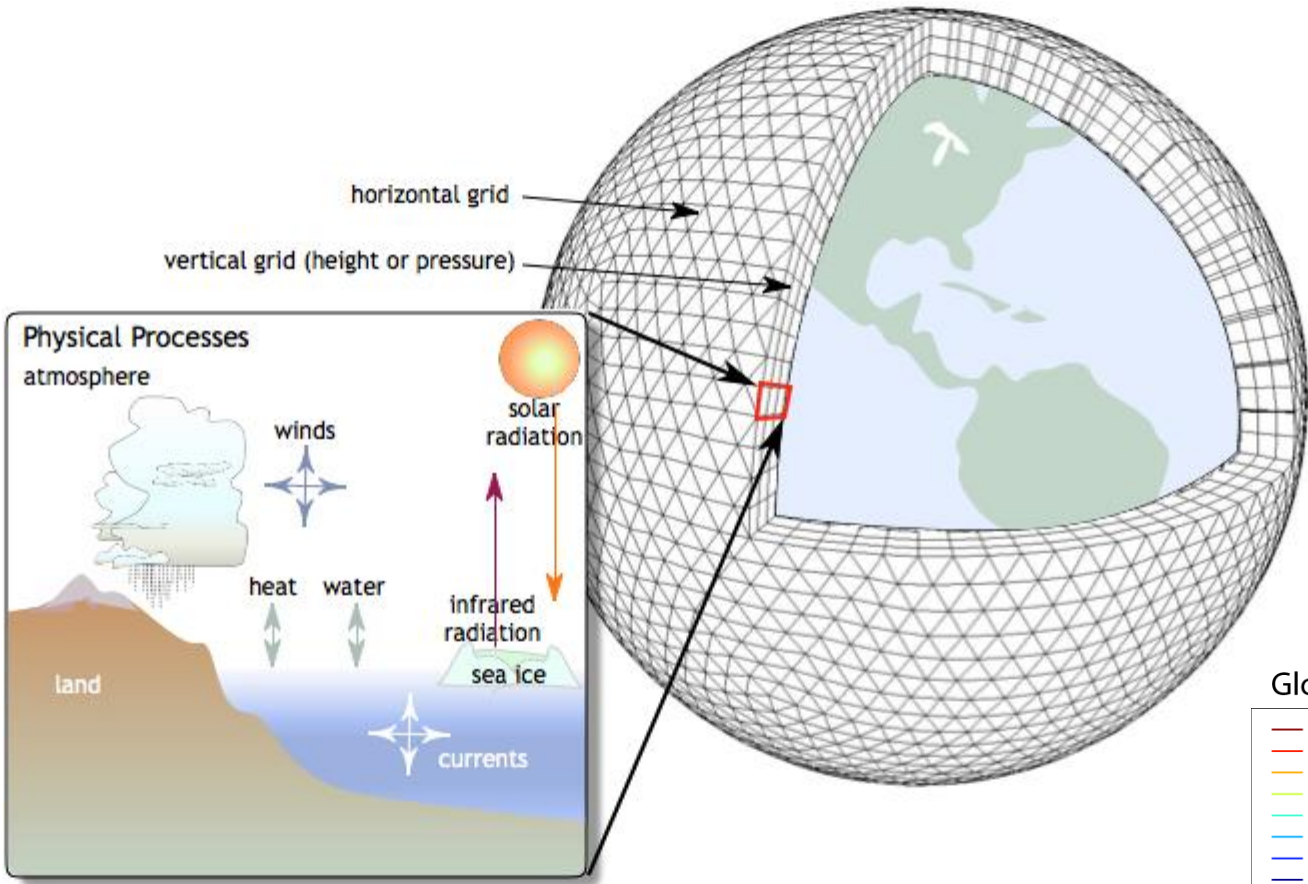
RCP8.5: very high emissions

Sources of uncertainty in climate projections

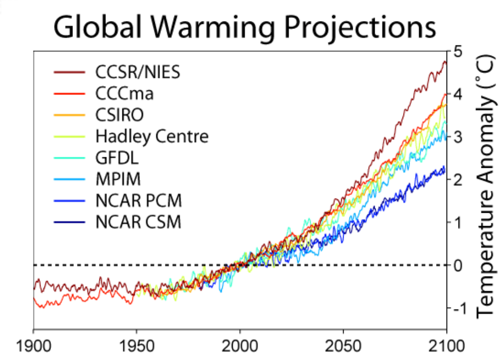


GCMs

General Circulation Models (or Global Climate Models)

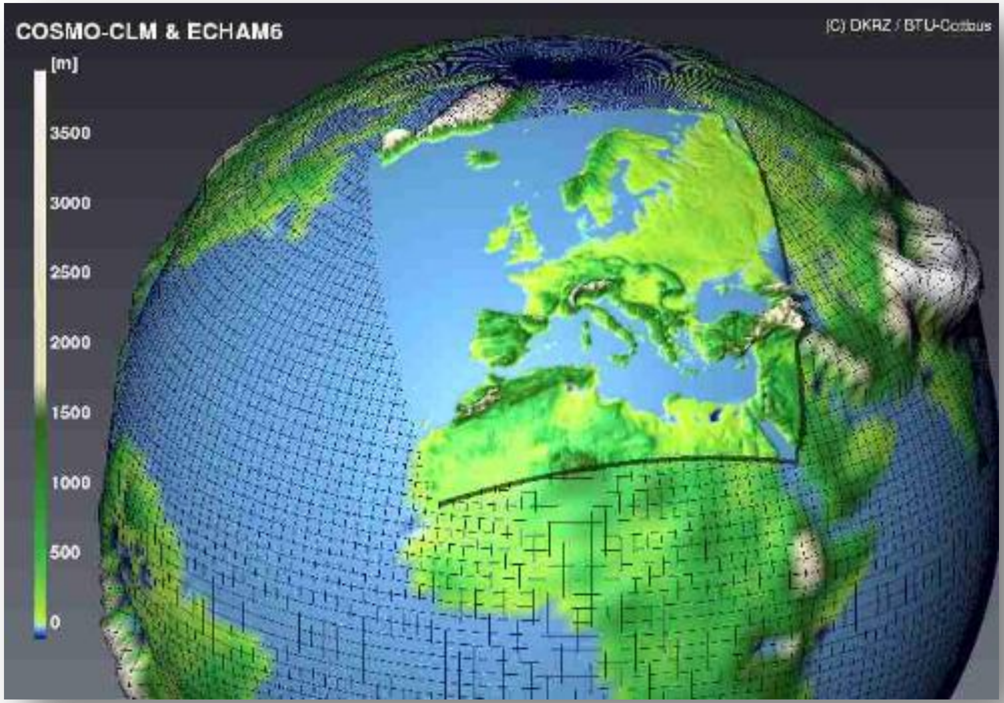


- Global
- Coarse resolution e.g. 200 x 200 km
- Ocean circulation included



RCMs

Regional Climate Models



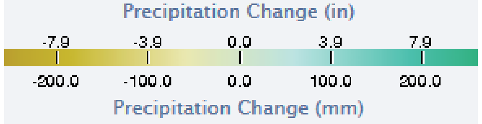
- Regional (limited area)
- Fine resolution
  e.g. 25 x 25 km
- Similar to Weather Prediction Models
- Nested in GCM

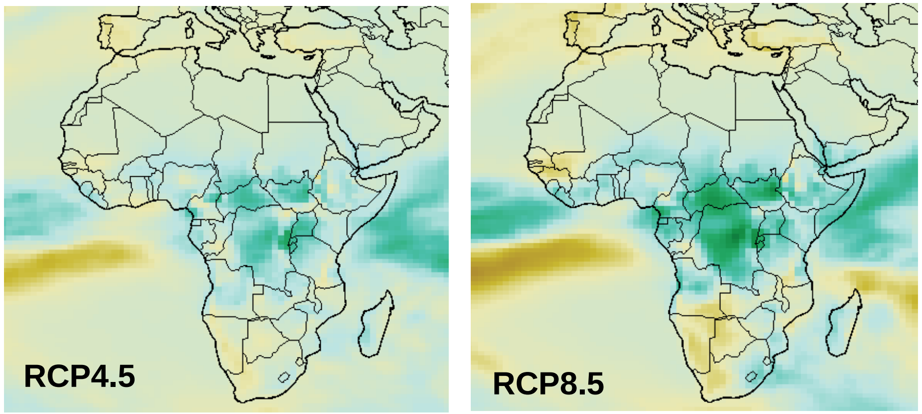
Climate change & hydropower development

Hydropower development needs long-term perspective

- Hydropower development:
  - long-term infrastructure investment
  - several decades of life cycle
- Clear temperature increase projected within few decades
- Precipitation projections with higher uncertainty
- Even very long term trends (second half of the century) are of high relevance for strategic planning

2061-2080 - 1986-2005
IPCC AR5 GCM results
Source: NCAR

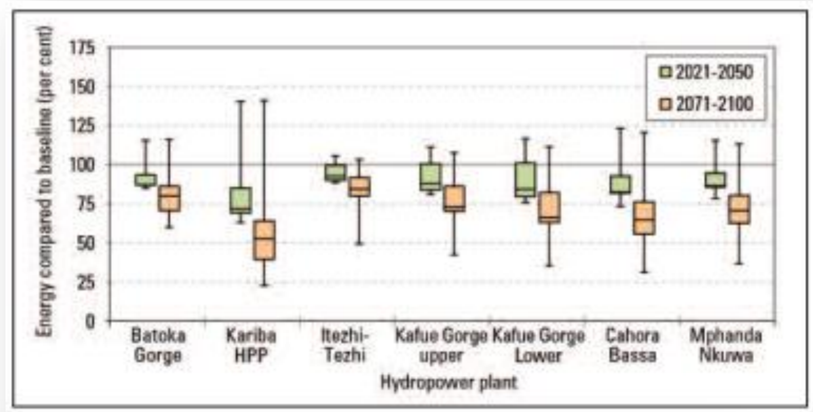


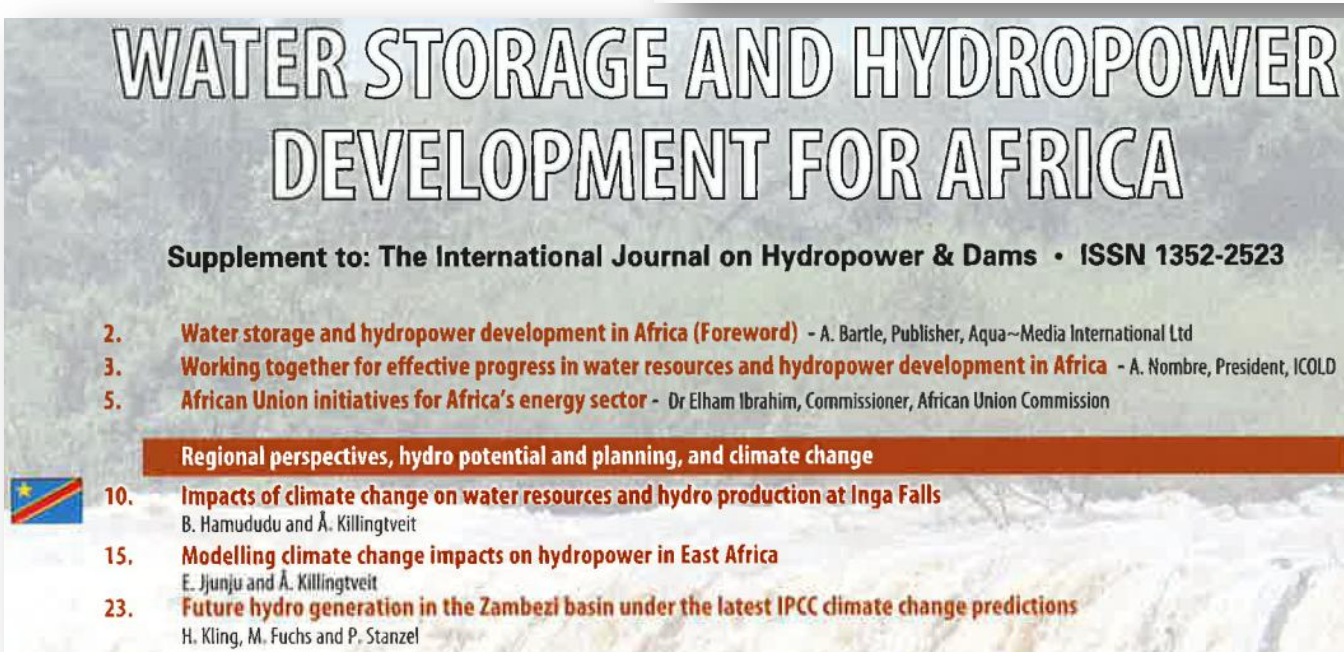


Impact on hydropower

Growing attention in science and engineering

- Growing concern on possible impacts of climate change on hydropower generation in Africa
- Decrease in future generation expected in southern Africa (Zambezi)




WATER STORAGE AND HYDROPOWER DEVELOPMENT FOR AFRICA

Supplement to: The International Journal on Hydropower & Dams • ISSN 1352-2523

2. Water storage and hydropower development in Africa (Foreword) - A. Bartle, Publisher, Aqua~Media International Ltd
3. Working together for effective progress in water resources and hydropower development in Africa - A. Nombre, President, ICOLD
5. African Union initiatives for Africa's energy sector - Dr Elham Ibrahim, Commissioner, African Union Commission

Regional perspectives, hydro potential and planning, and climate change

10. Impacts of climate change on water resources and hydro production at Inga Falls
B. Hamududu and Å. Killingtveit
15. Modelling climate change impacts on hydropower in East Africa
E. Jjunju and Å. Killingtveit
23. Future hydro generation in the Zambezi basin under the latest IPCC climate change predictions
H. Kling, M. Fuchs and P. Stanzel

Impact and Adaptation

Growing investors' awareness

- New focus of financing institutions:
  - Assessment of climate risk
  - Managing climate uncertainty
  - Climate change adaptation

MANAGING UNCERTAINTY IN HYDROPOWER AND WATER PROJECTS

10:00-17:00, Monday June 22, 2015

The World Bank I Building, 1850 I Street, NW, Washington, DC

Room I2-220

The World Bank disburses billions of dollars annually in long-term projects. Yet deep uncertainties, such as climate change, oil prices, and epidemics, to mention a few, pose formidable challenges to making near-term decisions that make long-term sense.

Hydropower investments are particularly sensitive to changes in climate and socio-economic conditions. The directions paper for the World Bank Group's energy sector mentions the WBG's firm commitment to the responsible development of hydropower projects, especially in regions like Sub-Saharan Africa and South Asia, where significant potential remains to be tapped. For many countries, hydropower represents the largest source of affordable renewable energy. The WBG engages in hydropower projects of all sizes and types-run of the river, pumped storage, and reservoirs - including off-grid projects meeting decentralized rural needs. In many cases reservoir projects will be multipurpose, incorporating integrated water resource management. But, one of the essential values of hydropower infrastructure investment, its long life, can make it vulnerable to future, uncertain changes in climate.

TOPICS

- Incorporating climate risk into financing
- Latest development in climate modelling and services
- Dealing with uncertainties in climate information
- Linking climate analyses to investment design

TARGET GROUPS

Consultants, experts and specialists involved in climate risk analyses

DATE

2 June 2015

LOCATION

Rond-Point Robert Schuman, 6 B-1040 Brussels

PARTICIPATION

Attendance is free of charge. Places are limited and will be allocated on a first come first served basis

LANGUAGE

The language for the day will be English

Concept

Development banks increasingly need to assess the risks posed by a changing climate, in order to safeguard adaptation investment decisions.

Within this context the Climate Service Center 2.0 in cooperation with the European Financing Institutions Working Group on Climate Change Adaptation (EUFIWACC) are holding an information day. Consultants, who carry out climate risk assessments for EUFIWACC members, are increasingly required to make concrete statements about climate risks. This information day is intended to provide a forum for dialogue and exchange, to further strengthen the process of delivering climate risk assessments. To this end, EUFIWACC members will report on the current requirements and expectations of the banks.

In addition, experts from the Climate Service Center 2.0 will provide practice relevant information on a range of different topics, including climate data access and availability, assessing the quality of climate information with respect to their robustness and usability, and their application in climate risk assessments.

Objectives of the day

- Knowledge building on climate-related requirements of the development banks
- Transfer of knowledge on availability, nature, extent and quality of climate data
- Presentation of methods for the analysis of climate data

Format

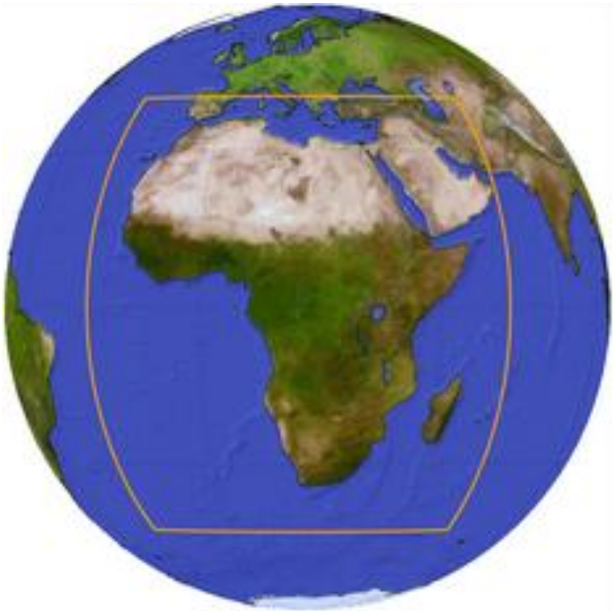
This is a one day event with speakers from the EUFIWACC member organizations, and the Climate Service Center 2.0.

Climate change projections for Africa

CORDEX-Africa

- Most detailed climate projections currently available for Africa

- Available CORDEX-Africa simulations (Dec 2015):
  - 4 RCMs
  - 15 RCM/GCM combinations
  - 2 emission scenarios (RCP4.5, RCP 8.5)
  - ➢ 30 RCM projections until 2100



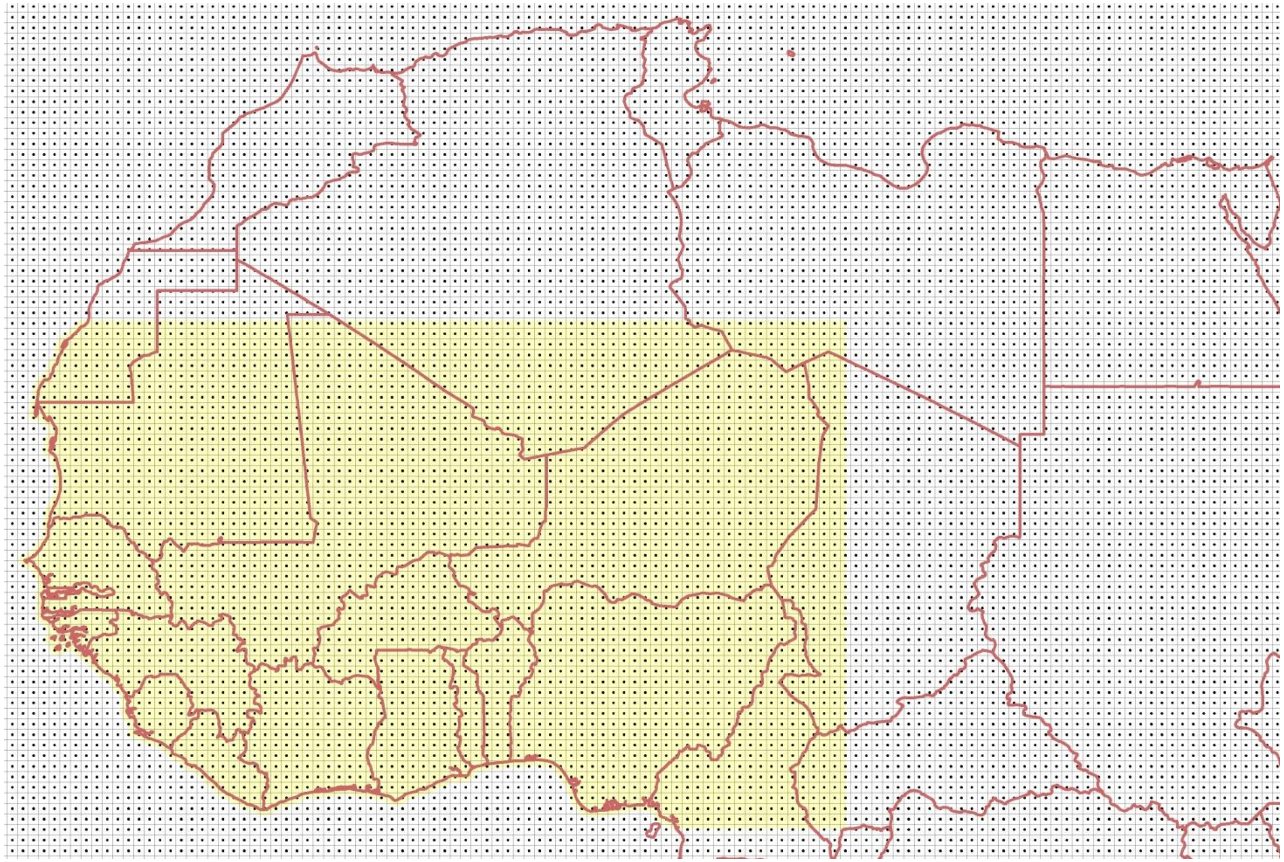
CORDEX-Africa domain (source: www.cordex.org)

- Simulations by world-class climate science institutions:
  - Swedish hydro-Meteorological Institute SMHI (RCA4)
  - Royal Netherlands Meteorological Institute KNMI (RACMO22T)
  - Danish Meteorological Institute DMI (HIRHAM5)
  - German institutions (mainly HZG, BTU Cottbus and PIK: COSMO-CLM)

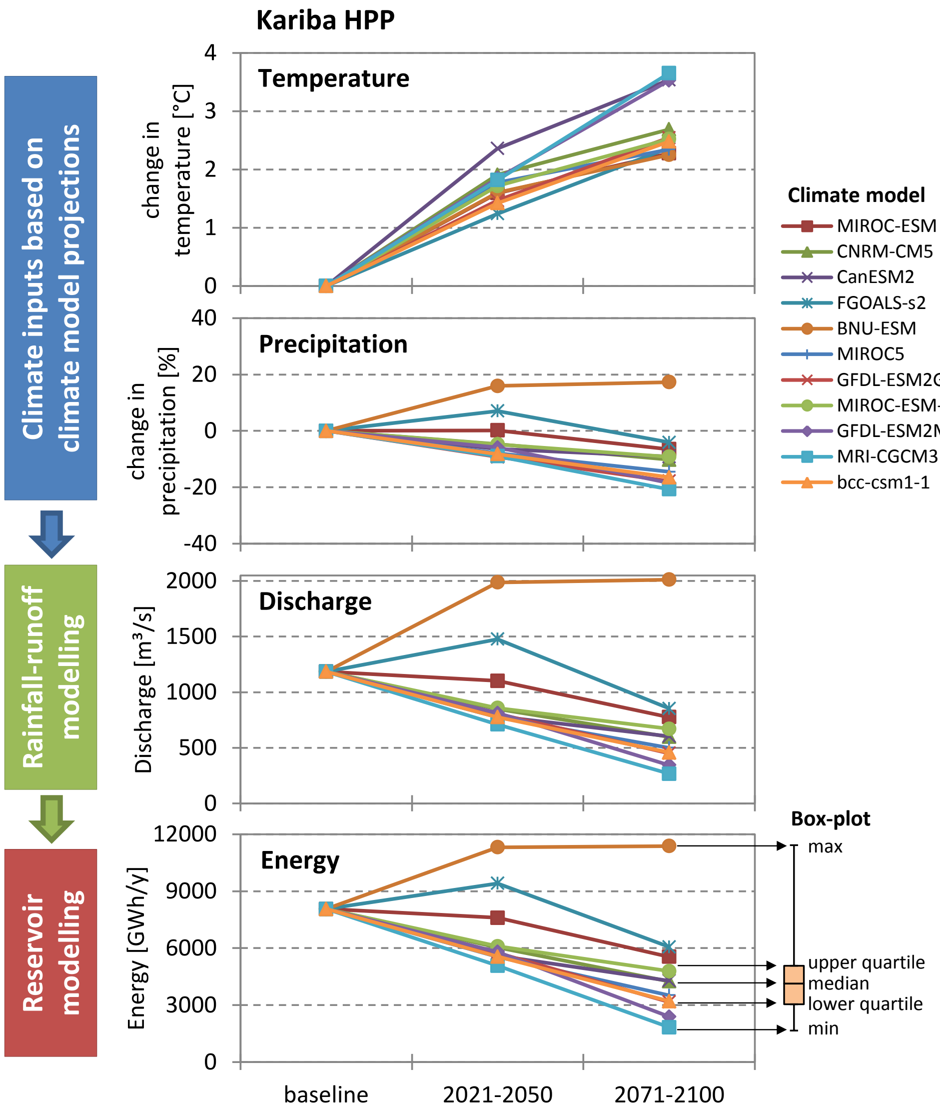
Climate change projections for Africa

CORDEX-Africa

- Spatial resolution of CORDEX-Africa simulations: 0,44°
- ~ 3400 gridpoints for the ECOWAS domain



General method of previous climate change impact studies



Used for quantification of uncertainty

Climate change study for West Africa

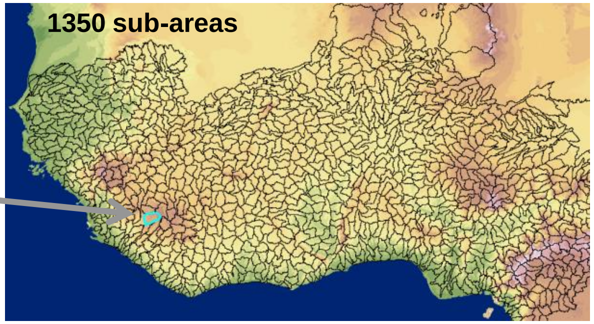
Method

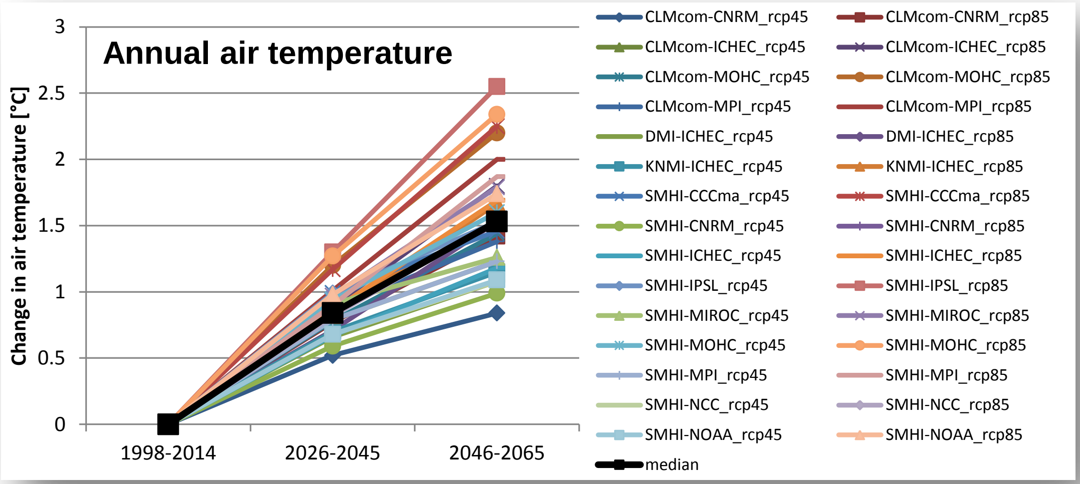
For each of the 30 CORDEX RCM runs, the following steps are performed:

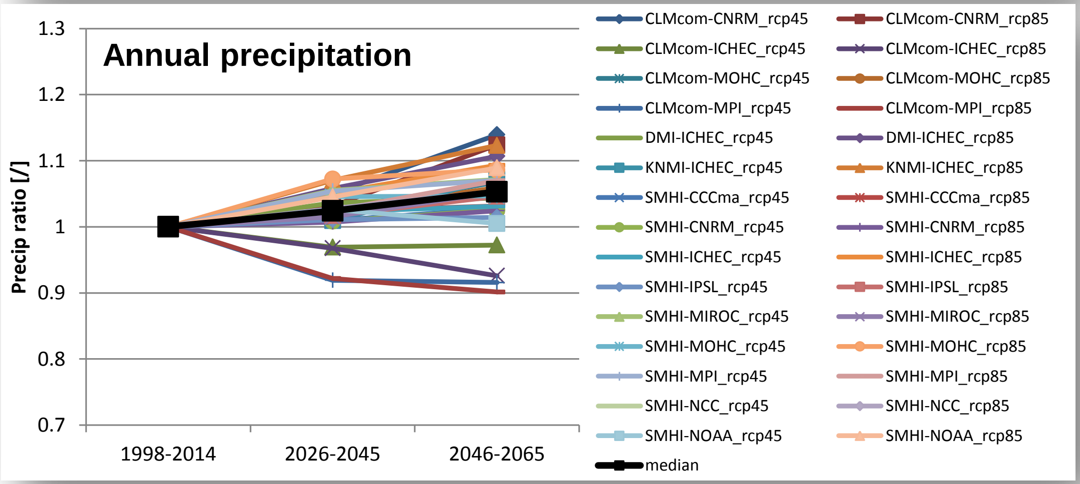
- Extract precipitation and temperature data from archived RCM runs
  - Historical run 1951-2005
  - Future run (emission scenario) 2006-2100
- Determine climate change signals between reference period and future
  - Reference period: 1998-2014
  - Future periods: 2026-2045 and 2046-2065
- Re-run water balance model (60 new runs) with future precipitation and temperature/evapotranspiration according to climate change signals:
  - ➢ Future runoff, future streamflow, future hydropower potential
- Summarize uncertainty in projections for 2026-2045 and 2046-2065
  - Median of 30 projections
  - Lower and upper quartile of 30 projections

Climate change

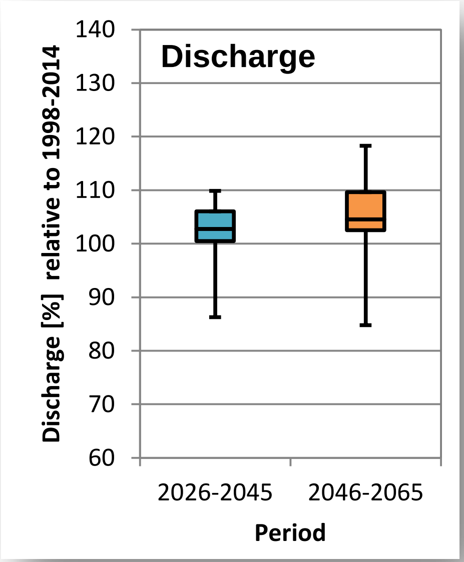
Example for upper Makona River (Guinea)





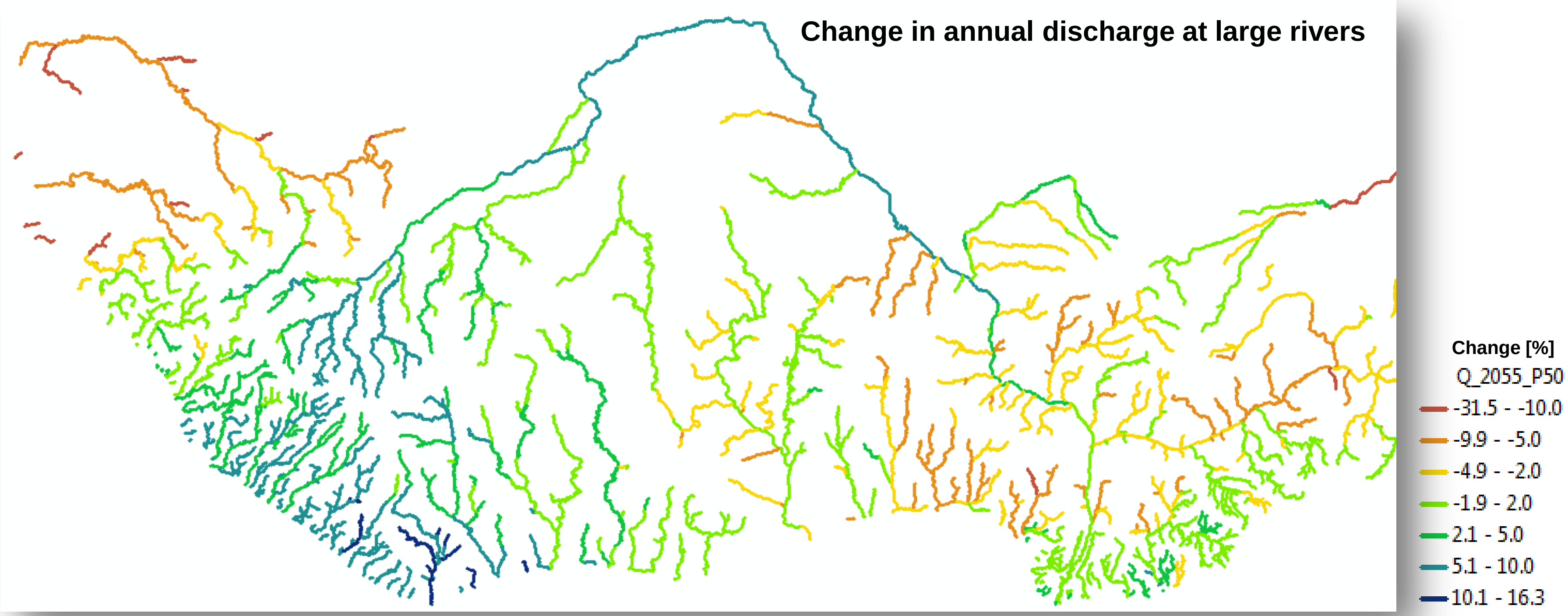


Water balance model



Climate change projection for 2046-2065 vs. 1998-2014

Median projection out of 30 climate model runs



Future change in discharge directly affects future hydropower potential.

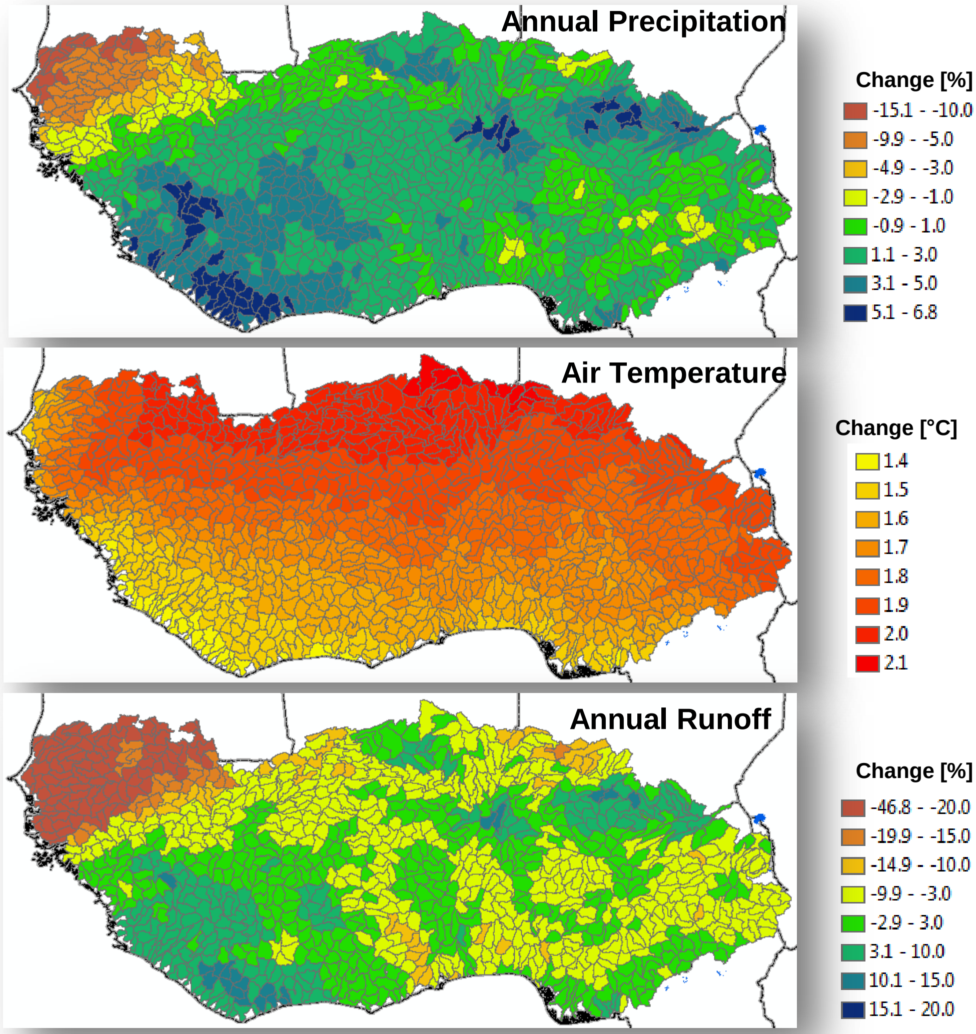
Climate change results: River network

Attribute list for 500,000 river reaches, part 2/2

- ...
- Q_YEAR: Mean annual discharge (m^3/s) simulated for the period 1998-2014
- Q_JAN: Mean monthly discharge (m^3/s) 1998-2014 in January
- Q_FEB: Mean monthly discharge (m^3/s) 1998-2014 in February
- Q_MAR: Mean monthly discharge (m^3/s) 1998-2014 in March
- Q_APR: Mean monthly discharge (m^3/s) 1998-2014 in April
- Q_MAY: Mean monthly discharge (m^3/s) 1998-2014 in May
- Q_JUN: Mean monthly discharge (m^3/s) 1998-2014 in June
- Q_JUL: Mean monthly discharge (m^3/s) 1998-2014 in July
- Q_AUG: Mean monthly discharge (m^3/s) 1998-2014 in August
- Q_SEP: Mean monthly discharge (m^3/s) 1998-2014 in September
- Q_OCT: Mean monthly discharge (m^3/s) 1998-2014 in October
- Q_NOV: Mean monthly discharge (m^3/s) 1998-2014 in November
- Q_DEC: Mean monthly discharge (m^3/s) 1998-2014 in December
- Q_2035_P25: Change in future mean annual **discharge** in % (**2026-2045** vs. 1998-2014) for the **lower quartile** simulation using 30 RCM runs
- Q_2035_P50: Change in future mean annual **discharge** in % **(2026-2045** vs. 1998-2014) for the **median** simulation using 30 RCM runs
- Q_2035_P75: Change in future mean annual **discharge** in % (**2026-2045** vs. 1998-2014) for the **upper quartile** simulation using 30 RCM runs
- Q_2055_P25: Change in future mean annual **discharge** in % **(2046-2065** vs. 1998-2014) for the lower quartile simulation using 30 RCM runs
- Q_2055_P50: Change in future mean annual **discharge** in % (**2046-2065** vs. 1998-2014) for the median simulation using 30 RCM runs
- Q_2055_P75: Change in future mean annual **discharge** in % (**2046-2065** vs. 1998-2014) for the upper quartile simulation using 30 RCM runs

Climate change projection for 2046-2065 vs. 1998-2014

Median projection out of 30 climate model runs



Climate change results: Sub-areas

Attribute list for 1060 sub-areas, part 1/3

- NB: ID number of sub-area
- AREA: local size (km²) of sub-area
- PRECIP_Y: Mean annual precipitation (mm) in the period 1998-2014
- ETA_Y: Mean annual actual evapotranspiration (mm) simulated for the period 1998-2014
- RUNOFF_Y: Mean annual runoff (mm) simulated for the period 1998-2014
- TEMP_Y: Mean annual air temperature (°C) in the period 1998-2014
- P_2035_P25: Change in future mean annual **precipitation** in % (**2026-2045** vs. 1998-2014) for the **lower quartile** projection of 30 RCM runs
- P_2035_P50: Change in future mean annual **precipitation** in % (**2026-2045** vs. 1998-2014) for the **median projection** of 30 RCM runs
- P_2035_P75: Change in future mean annual **precipitation** in % (**2026-2045** vs. 1998-2014) for the **upper quartile** projection of 30 RCM runs
- E_2035_P25: Change in future mean annual **actual evapotranspiration** in % (2026-2045 vs. 1998-2014) for the lower quartile simulation
- E_2035_P50: Change in future mean annual **actual evapotranspiration** in % (2026-2045 vs. 1998-2014) for the median simulation
- E_2035_P75: Change in future mean annual **actual evapotranspiration** in % (2026-2045 vs. 1998-2014) for the upper quartile simulation
- R_2035_P25: Change in future mean annual **runoff** in % (2026-2045 vs. 1998-2014) for the lower quartile simulation using 30 RCM runs
- R_2035_P50: Change in future mean annual **runoff** in % (2026-2045 vs. 1998-2014) for the median simulation using 30 RCM runs
- R_2035_P75: Change in future mean annual **runoff** in % (2026-2045 vs. 1998-2014) for the upper quartile simulation using 30 RCM runs
- T_2035_P25: Change in future mean annual **air temperature** in °C (2026-2045 vs. 1998-2014) for the lower quartile projection of 30 RCM runs
- T_2035_P50: Change in future mean annual **air temperature** in °C (2026-2045 vs. 1998-2014) for the median projection of 30 RCM runs
- T_2035_P75: Change in future mean annual **air temperature** in °C (2026-2045 vs. 1998-2014) for the upper quartile projection of 30 RCM runs
- P_2055_P25: Change in future mean annual **precipitation** in % (**2046-2065** vs. 1998-2014) for the lower quartile projection of 30 RCM runs
- etc.
- ...

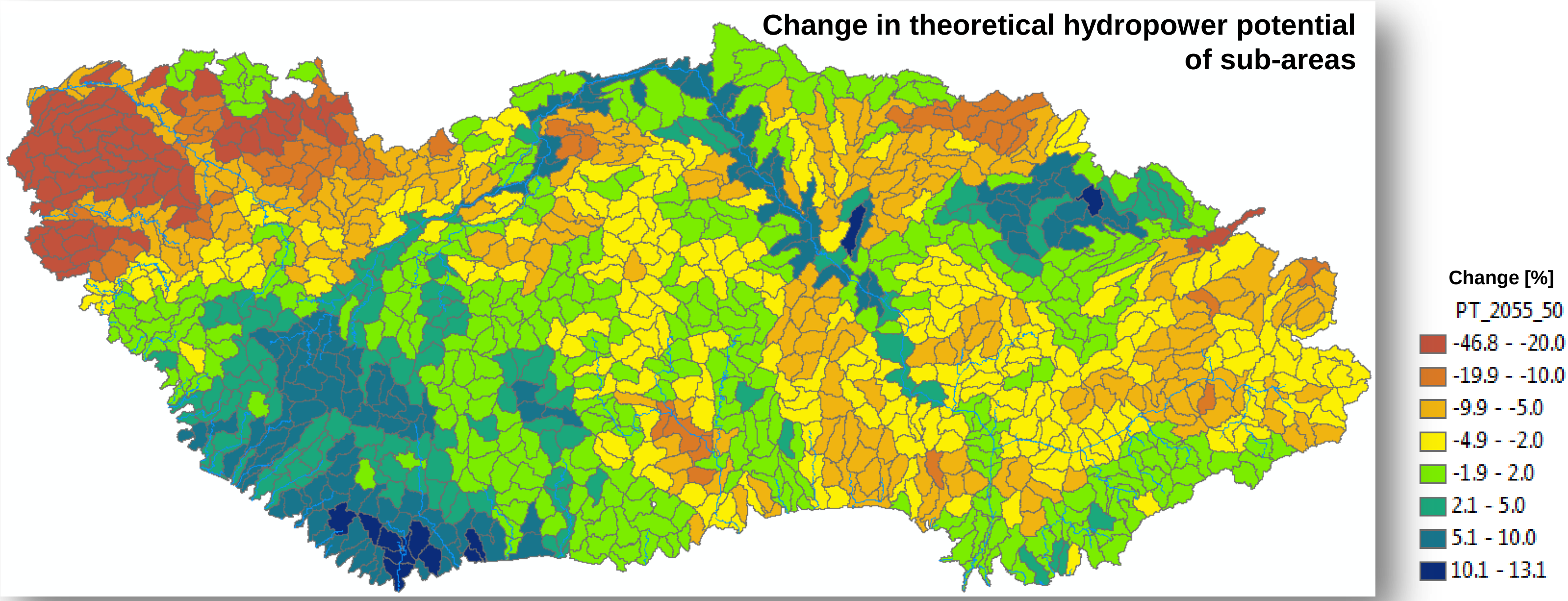
Climate change results: Sub-areas

Attribute list for 1060 sub-areas, part 3/3

- ...
- PT_2035_25: Change in future **hydropower potential** in % (**2026-2045** vs. 1998-2014) for the **lower quartile** simulation using 30 RCM runs
- PT_2035_50: Change in future **hydropower potential** in % (2026-2045 vs. 1998-2014) for the **median** simulation using 30 RCM runs
- PT_2035_75: Change in future **hydropower potential** in % (2026-2045 vs. 1998-2014) for the **upper** quartile simulation using 30 RCM runs
- PL_2035_25: Change in future **hydropower potential** in % (2026-2045 vs. 1998-2014) of **local rivers** (originating from the same sub-area) for the lower quartile simulation using 30 RCMs
- PL_2035_50: Change in future **hydropower potential** in % (2026-2045 vs. 1998-2014) of **local rivers** (originating from the same sub-area) for the median simulation using 30 RCMs
- PL_2035_75: Change in future **hydropower potential** in % (2026-2045 vs. 1998-2014) of **local rivers** (originating from the same sub-area) for the upper quartile simulation using 30 RCMs
- PT_2055_25: Change in future **hydropower potential** in % (**2046-2065** vs. 1998-2014) for the lower quartile simulation using 30 RCM runs
- etc.

Climate change projection for 2046-2065 vs. 1998-2014

Median projection out of 30 climate model runs



➡ Regions with positive/negative impact of climate change on hydropower can be identified.

Summary of climate change study

Main findings

- Climate change must be considered in state-of-the-art hydropower development.
- The most detailed climate change projections currently available for Africa were used in this study
- Considerable warming is expected in the future, leading to higher evaporation losses
- Changes in future precipitation show regional differences (increase/decrease)
- Expected changes in future discharge:
  - Increase in e.g. Sierra Leone, Liberia
  - Decrease in e.g. lower Senegal basin
  - No significant change in e.g. Volta basin
- Climate change is not a worst-case scenario for hydropower in West Africa.

Climate change study

Group discussion

- General questions about the presented study?
  - Methodology?
  - Results?

- What results are of special interest for your country?

- Previous climate change studies in your country?
  - What methods were used?
  - Dissemination of results? Reports, maps, websites, etc.?
  - Have you been involved in the study?

- Perception of climate change in your country?
  - Is climate change already observed?
  - Is climate change perceived as a threat or opportunity?

Overall summary of today's training

- New hydropower related GIS layers have been created
  - Existing hydropower plants layer
  - Climatic zones layer
  - River network layer
  - Sub-areas layer
  - Country reports
  - Climate change (incorporated into other layers)

- Results will be online in ECOWREX within the next months

- The results help to identify regions that are attractive for hydropower development

- Training tomorrow: GIS layers, group work, practice examples
  - Hydropower classification: plant type, plant size
  - Practice examples
    - Installed capacity & energy calculation
    - Water balance & climate change calculation

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