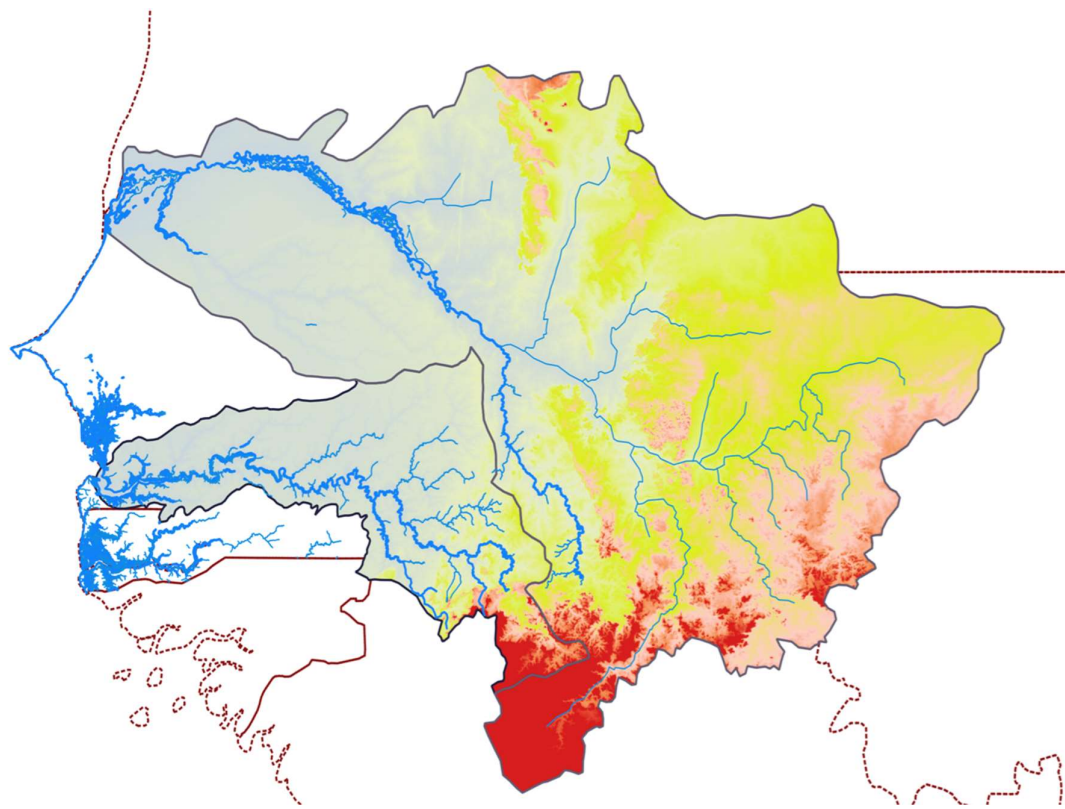




## Inception Report

# CLIMATE VULNERABILITY AND WATER RESOURCES VARIABILITY IN WEST AFRICA. SENEGAL AND GAMBIA RIVER BASIN CASES STUDIES



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## Summary

This inception report presents the project "Climate vulnerability and water resources variability in West Africa. Senegal and Gambia river basin cases studies ". It is part of the ACEWATER2 program and is under the umbrella of the Regional Atlas of Water Cooperation.

This report describes the background of the study, the objectives and scope of the work. The Senegal river basin (SRB) is one of the catchments selected by WANWATCE. The Gambia river basin (GRB) have been added by the UCAD's team, due to their similarities and proximity. The team's will is to do thorough job and then replicate it in the other basin accross West Africa.

The overall goal of this project is to contribute to better understanding of climate variability and its impacts on water resources availability in trans boundary watersheds of West Africa, particularly in Senegal and Gambia river basin. In the actual Africa's environmental context, there is a need to understand and mainstream the climate variability and related economic vulnerability. The effects on water resources availability are a major challenge across West Africa and the Sahel zone.

The development of databases at basin scale is to perform climate variability/risk analysis by using traditional statistic tools and also new approach with hydrological modeling. At national level, the study will focus on development of climate scenarios based on ground data and simulation tools.

According to the ToRs, the three (03) milestones of the project are to be delivered to JRC between December 2017 and February 2019.

## List of acronyms and abbreviations

<b>2iE:</b>	International Institute for Water and Environment Engineering
<b>AGRHYMET:</b>	Agriculture, Hydrology, Meteorology
<b>AMMA:</b>	Multidisciplinary Analysis of African Monsoon
<b>AMCOST:</b>	African Minister's Council for Sciences and Technology
<b>AMCOW:</b>	African Minister's Council on Water
<b>ANACIM:</b>	Agence Nationale de l'Aviation Civile et de la Météorologie du Sénégal
<b>AUC:</b>	African Union Commission
<b>DGPRES:</b>	Direction de la Gestion et de la Planification des Ressources en Eau
<b>ECOWAS:</b>	Economic Community Of West African States
<b>EDEQUE:</b>	Ecole Doctorale "Eau, Qualité et Usages de l'Eau"
<b>EDEQUE:</b>	Ecole Doctorale "Eau, Qualité et Usages de l'Eau"
<b>FRIEND-AOC:</b>	Flow Regimes from International Experimental and Network Data – Western and Central Africa
<b>IHP:</b>	International Hydrological Program
<b>IRD:</b>	Institut de Recherche pour le Développement
<b>JRC:</b>	Joint Research Centre/European Commission
<b>KNUST:</b>	Kwame Nkrumah University of Sciences and Technology (Ghana)
<b>NEPAD:</b>	
<b>NWRI:</b>	National Water Resources Institute
<b>NWRI:</b>	National Water Resources Institute (Nigeria)
<b>OMVG:</b>	Organisation pour la Mise en Valeur du fleuve Gambie
<b>OMVS:</b>	Organisation pour la Mise en Valeur du fleuve Sénégal
<b>RWESCK:</b>	Regional Water and Environmental Sanitation Centre Kumasi (Ghana)
<b>UCAD:</b>	Université Cheikh Anta Diop de Dakar
<b>UCAD:</b>	University of Cheikh Anta Diop (Senegal)
<b>UNESCO:</b>	United Nation Educational, Scientific and Cultural Organization
<b>UNIBEN:</b>	University of Benin (Nigeria)
<b>UNIBEN:</b>	University of Benin (Nigeria)
<b>WANWATCE:</b>	West African Network
<b>WANWATCE:</b>	Western African Network of Water Centres of Excellence
<b>WASCAL:</b>	West African Science Service Center on Climate Change and Adapted Land Use

## Introduction

The Doctorate School “Water, Water Quality and Water Uses of Cheikh Anta Diop University (EDEQUE/UCAD) Dakar (Senegal), is one of the Five members of the WANWATCE (Western African Network of Centers of Excellence on Water Sciences and Technologies).

Established in 2010, WANWATCE network (Fig. 1) is constituted by EDEQUE/UCAD (Senegal), 2iE (International Institute for Water and Environment Engineering) of Ouagadougou (Burkina Faso), RWESCK/KNUST (Regional Water and Sanitation Centre, Kumasi / Kwame Nkrumah University of Sciences and Technology, Kumasi (Ghana), University of Benin, Benin City (Nigeria) and, National Water Resources Institute (NWRI) of Kaduna (Nigeria). The doctorate school EDEQUE of Cheikh Anta Diop University currently coordinates the network and hosts the Secretariat in the Campus 3 of UCAD.

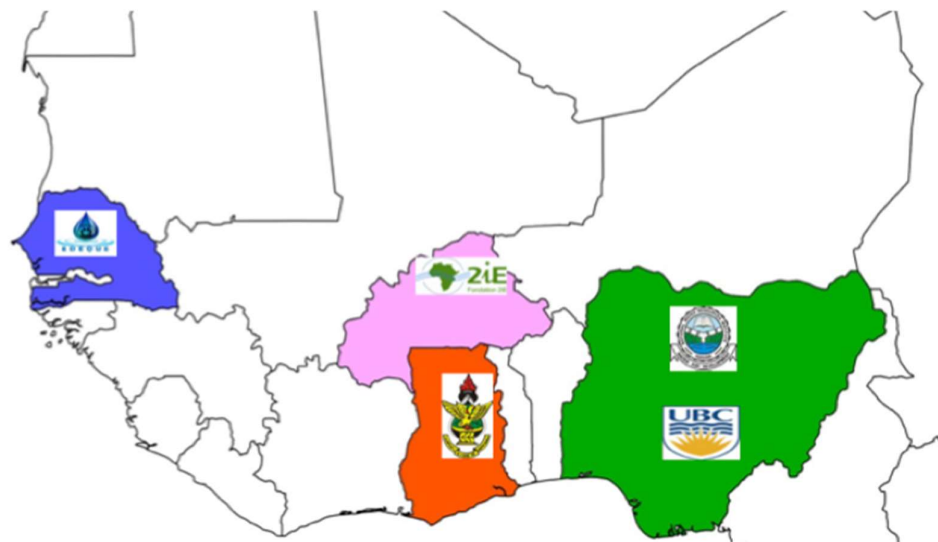


Fig. 1 - The Western Network of CoE of NEPAD on Water Sciences

During the first Phase of AUC-NEPAD Project, the main results of the Scientific Component were: the Identification of needs in terms of capacities in the two regions; Climate Variability Analysis in Western Africa and Implementation of training sessions and reporting.

In the framework of 2nd Phase of AUC-NEPAD African Network of Centers of Excellence on Water Sciences and Technology (ACEWATER2), the development of a Regional Atlas on Water Cooperation is planned since the first ACEWATER2 Meeting in Cape Town in May 2016. This Atlas is aimed to improve regional data accessibility, for more effective water resources management and water related disasters and/or conflict impacts reduction through mitigation strategies, building resilience and reducing vulnerability. The main objective of the Scientific Activities Component (SC) is to strengthen institutional networking and improve research support to policy making in the water sector on the following topics:

- Analysis of the Climate Variability in Africa; ☐
- Water Resources Security and SDGs – Online Atlas on Water Cooperation; ☐
- African Water-Energy-Food Security Nexus Assessment.

According to discussions carried out by WANWATCE, the following thematic areas have been identified:

- Climate variability and extreme weather events and their impacts on the “WEF Nexus”
- Water Security and Atlas
- Deltas and Estuaries issues in the selected Basins
- Transboundary water governance and management.

Two trans boundary River Basins have been selected at sub regional level (Fig. 2): Senegal and Niger. But work on these two catchments seems to be very complex. That’s why EDEQUE/UCAD select the Senegal and Gambia Rivers on which thorough job will be done. The idea is to identify good practices on Senegal River basin and then replicated them in other basins. This is to strengthen the collaboration inside the network and to provide a common reference base for all CoEs.

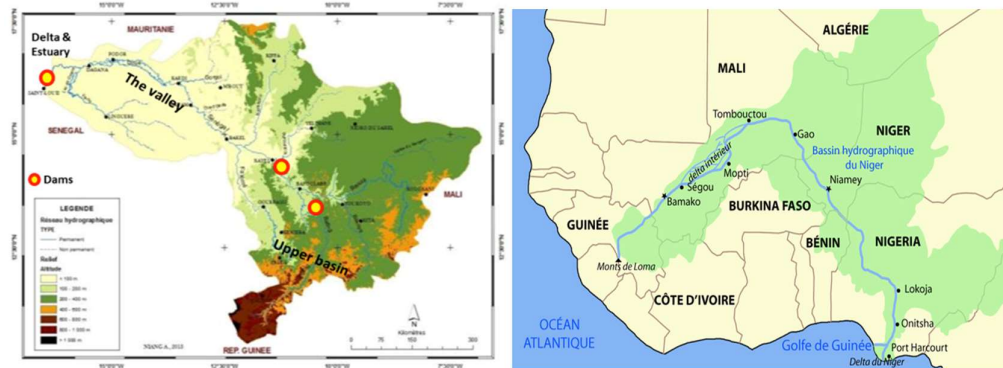


Fig. 2 – The transboundary river basins selected in West Africa

This study is part of the project: “The African Networks of Centers of Excellence on Water Sciences PHASE II (ACEWATER 2)” that aims at fostering sustainable capacity development at scientific, technical and institutional level in the water sector. The project supports twenty (20) AU-NEPAD African Network of Centers of Excellence in Water Sciences and Technology (CoEs) organized in three regional networks, in conducting high-end scientific research on water and related sectors, in order to provide effective scientific and educational support to governments. The project is implemented in partnership between UNESCO, in charge of the human capacity development component, and the JRC that coordinates the scientific component and leads the project.

## Background of the study

West African region, particularly over Sahel zone, has experienced a long-term climate variability and climate change during the last decades. Despite some periods of respite, statistics are not truly pleading for a return to better climatic conditions, rainfall precisely. Beyond the structural aspect of this climatic variability, many effects were observed on socioeconomic activities and the implication of sociocultural practices. This situation reverberates dramatically on water resources and particularly on the hydrology of trans boundary basins like Senegal and Gambia.

In the 80<sup>th</sup>, the weakness of floods in the SRB leads to more severe salt intrusion that some years even exceeded Podor located 150 km to the river mouth. Data from the Bakel station illustrate this flow reduction in the Senegal River.

In Senegal, the isohyet 300 mm did a migration of several kilometers southbound. The estimations realized by the UNEP on water resources at the African scale, foresee a critical situation on the horizon 2025, particularly in the Sahel where some situations are already proved dramatic. Despite its outstanding hydric potentialities for a sahelian country, Senegal risks to experience water stress while it disposed of more than 4000 m<sup>3</sup>/pers/year in 1990. The historical period shows that Senegal is essentially a semi arid country. For the late twenty-first century and according to main scenarios, the whole country shifts toward arid conditions (Tall et al., 2016).

By 2035, according to the projections the rainfall will decrease from -3% to -20% while the temperatures will increase between + 1 °C and + 1.8 °C. in the Senegal river Basin, simulations carried out by Mbaye & al (2015) with MPI-HM (Max Planck Institute for Meteorology - Hydrology Model) demonstrate:

- Elevation of temperatures and reduction of rainfalls by the end of the century
- High variability of rainfalls and discharges in the upper basin
- Decrease of soil moisture and flows

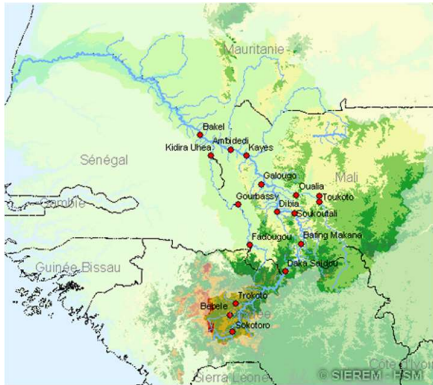
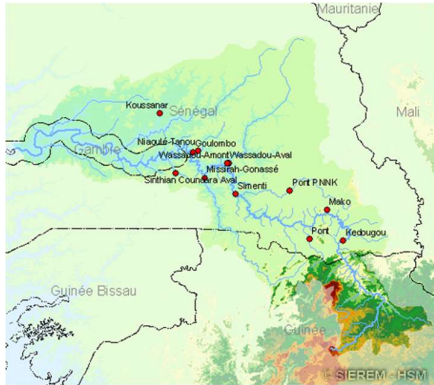
This climate variability (rainfalls) in a context where agriculture involves more than 80% of the population is enhancing the use of surface waters. Added to this, the current challenge represented the politic choice of Senegal through the “Plan Senegal Emergent” targeting self-Sufficiency in rice by 2017.

Since many decades, under the aegis of the OMVS, several programs have been implemented in the Senegal River Basin with the major objective to fight the effects of the climatic pejoration and the mobilization of surface water resources. Despite all these efforts, there is a lot to do in term of understanding of water resources variability and defining the suitable programs of attenuation of the vulnerability.

Beyond the structural aspect of this climatic variability, many effects were observed on socioeconomic activities and the implication of sociocultural practices. This situation reverberates dramatically on water resources and particularly on the hydrology of trans boundary basins like Senegal and Gambia. As groundwater recharge was no longer ensured in these conditions, food security was compromised for local communities. The response of OMVS was dams edification (Diama in 1985, Manantali in 1987 and now the second generation of infrastructures with Felou in 2013... and many others hydraulic infrastructures under construction). In the Gambia River Basin, OMVG is also developing programs and projects to improve water availability and for hydropower production at large scale.

The Senegal and Gambia River Basins are proposed as basins case study area for the Western Africa Network of Water Centers of Excellence (WANWATCE), in consideration of both their relevance and former/ongoing baseline characterization and modelling activities.

Western Africa basins pose many challenges from a perspective of Water-Energy-Food-Ecosystem (WEFE) nexus, including, among others, hydropower production, reservoir multipurpose optimization and release management, rainfed and irrigated agriculture development, impact of land use and agricultural practices (including livestock and fisheries), role of ecosystem services (natural parks, wetlands; delta region), pressures on resources due to population increase, climate variability/change and related extreme events risks (drought and flooding).

<b><u>Senegal River Basin (SRB)</u></b>	<b><u>Gambia River Basin (GRB)</u></b>
<ul style="list-style-type: none"> <li>• 300.000 km<sup>2</sup></li> <li>• 4 riparian states: Guinea, Mali, Mauritania and Senegal</li> <li>• OMVS as River Basin Authority</li> </ul> 	<ul style="list-style-type: none"> <li>• 77.000 km<sup>2</sup></li> <li>• 4 riparian states: Guinea, Guinea Bissau, Senegal and Gambia</li> <li>• OMVG as River Basin Authority</li> </ul> 

**Fig. 3 - The selected case studies: Senegal and Gambia River basins (maps from SIEREM)**



## Objectives and scope of the work

The general objective of the present study is to contribute to better understanding of climate variability/risks and its impacts on water resources availability in trans boundary watersheds of West Africa. It aims to address some relevant topics like climate variability analysis and climate risks assessment and evaluation of sustainable bridging-gap solutions, based on state-of-the-art reviews and scientific analysis. Based on scientific research on climate variability, conducted in the framework of first phase of ACEWATER project, and on former and ongoing analysis and modelling activities, specific actions are envisaged, taking into account scientific competencies of CoEs, regional Scientific Institutions (AGRHYMET, WASCAL Programme...), basins management organizations (OMVS, OMVG, ABN, etc.) and JRC.

This is in view of promoting an effective cooperation among key regional stakeholders, towards the development of a dynamic web African Atlas on Water Cooperation, supporting decision-making processes through scenarios-based-analysis. This system will provide a scientific baseline as well as scenarios and tools for decision making regarding water, energy and agricultural management within the river basin.

This work is to be done on climate variability, extreme events and impacts on hydrology in West Africa, focusing on Senegal and Gambia River basins. The main results to be given by the study are:

- report on climate database update covering the entire Senegal and the two basins (SRB and GRB),
- climate variability and trends analysis across West Africa,
- impact assessment of climate on hydrology in Western Africa (including data from gauging stations, metadata and existing modelling tools and assessments),
- capacity Building material for tailored training events

The current specific actions are to be implemented taking into account scientific competencies of both the Expert, belonging a specific Centre of Excellence, the others members of WANWATCE working in the same (scientific) field and the JRC, in view of an effective cooperation with key regional stakeholders.

## Methodology and work plan

In order to improve Western Africa climate database and to perform climate variability analysis and risks assessment relevant to Western Africa, the expert will particularly develop activities related to:

- i. Integration of Western Africa Climate database based on local and large scale data sources (ground gauging stations and related time series of rainfall and temperature, remote sensed datasets);
- ii. Climate Variability (CV) analysis to improve knowledge on climate baseline conditions in Western Africa, based on both ground gauging stations and remote sensed data sources;
- iii. Climate risk assessment on extreme events (droughts, floods), based on analysis of relevant indicators (i.e. SPI, SPEI, SFI), state of the art methodologies and statistical techniques (RFA - Regional Frequency Analysis, L-Moment).
- iv. Development of Capacity Building material for tailored training events.

Activities will be focused at the Western Africa scale, and in particular across the Senegal and the Gambia River Basins, in order to provide spatially continuous coverages, integrated by regional relevant case studies, according to OMVS priorities.

Scientific research outcomes will contribute to scientific capacity building activities to be delivered as workshops along the duration of the project. Trainings will address AU NEPAD WANWATCE, AMCOW experts, OMVS and OVG and other African Basin authority's experts and related national authorities under the boundaries of the ACEWATER2 project budget. The Expert will develop trainings contents and materials and engage himself to participate at the ACEWATER2 workshops, to be organized by JRC (not part of these ToRs).

All the project outcomes, both in terms of scientific reports, capacity building and training materials, database and calibrated models will be delivered to OMVS as support of the WANWATCE, in the framework of the ACEWATER2 project.

A least one scientific paper will be prepared and published in a peer reviewed journal to be identified.

Synergies and cross-cooperation with ongoing research programs and projects will be pursued, also from the JRC within the WEFE Nexus initiative.

## Milestones and timetable of the study

According to the ToRs given by JRC, the milestones are as follows:

- **WA.CVA.M1:** Inception Report, detailing the conceptual framework and table of contents of the report, architecture of the database, data availability, issues, challenges and possible solutions, overall planning of the work to be implemented (due 15<sup>th</sup> December 2017)
- **WA.CVA.M2 progress:** Report, baseline database, climate variability and trends analysis, impact on hydrology PROGRESS VERSION (due 30<sup>th</sup> Septembre 2018)
- **WA.CVA.M2 final:** Report, baseline database, climate variability and trends analysis, impact on hydrology FINAL VERSION (due 28<sup>th</sup> February 2019)

The expert will report every month to the JRC on the progress, problems encountered, etc. The deliverables should be sent to César Carmona Moreno, [cesar.carmona-moreno@ec.europa.eu](mailto:cesar.carmona-moreno@ec.europa.eu)

The expected timetable for the project is presented below, based on milestones and general agenda given by JRC.

Milestones	Description of the work	2017		2018												2019		
		N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	
<b>WA.CVA.1.0</b> Inception report	Detailing job scope, objectives, scientific activities and overall work plan																	
<b>WA.CVA.1.1</b> Report on climate database update, climate variability and trends analysis, impact assessment of climate on hydrology in Western Africa	i. Climate database update, integrating former ACEWATER1 database with Senegal basin datasets and contributions from other CoEs;																	
	ii. Climate variability analysis, based on ground stations and remote sensed data sources, and extreme climate events environmental (i.e. flooding, drought) and social impacts analysis, food and water insecurity;																	
	iii. Impact of climate variability and trends, in a WEF perspective, on water availability,																	
<b>WA.CVA.1.2</b> Capacity Building material	Presentations on theory, practice, baseline database, model design and implementation, analysis outcomes																	

## Team and Partners

The expert in charge of this contract is Prof. Awa NIANG FALL; she is responsible of delivering report, and all contractual aspects. She will work closely with:

- Prof Saïdou Moustapha SALL, responsible of LPAO-SF laboratory and expert of climate modeling
- Prof Alioune KANE, coordinator of WANWATCE network, facilitator for contacts with other CoEs and other partners

Dr Coura KANE in post-doctoral position will also collaborate and assist this study. Two students have been identified to be involved in this study: Abdoulaye FATY (doctoral student) and Mbayang THIAM (Master Student).

Main Partners for this study are:

- OMVS (Senegal River Basin Organization),
- OMVG (Gambia River Basin Organization)
- ANACIM
- IRD / Hydro Sciences Montpellier / SIEREM
- Ministry of Higher Education and Research
- General Directorate of Research and Innovation (Senegal)
- Ministry of Hydraulic and Sanitation
- ECOWAS (Economic Community Of West African States),
- AGRHYMET
- AMCOW (African Minister's Council on Water)
- AMCOST (African Minister's Council for Sciences and Technology)
- WASCAL (West African Science Service Center on Climate Change and Adapted Land Use) Program
- UNESCO IHP & FRIEND AOC

At national level, Centers of Excellence work closely with ministries in charge of water and sanitation and research institutions.

## Risks and mitigation measures

According to the overall objectives and methodology developed in this project, there is very minor risks related to:

- Institutional and administrative arrangements with services in charge of hydro-climatic data at national (Senegal) and basin level (OMVS and OMVG);
- Scope of the work with two dimensions:
  - o national with analysis of CV and trends in rainfall and temperature(“ wxcv
  - o sub regional with two basins and six states (Senegal, Mauritania, Gambia, Mali, Guinea and Guinea Bissau)

The general measures of mitigation are similar to what have been developed in other projects where UCAD have involved (Vulnerability Assessment, AMMA, ACT4SSAWS...). The demarch is to develop and reinforce existing institutional networks in the area of climate and hydrology, for data and experience sharing.

Another important measure is to mention data provider in all publications and encourage co-publications with researchers involving in these institutions. An other way is to get doctoral students involved in the development of the project with some objectives directly linked to their own research action.

Data access and sharing is a big issue for researchers in sub saharan Africa but many strategies can be developed to resolve this problem. An other alternative is to use climate re-analysis or data from meteorological satellite.

## Proposed contents of the report

### 1. Presentation of the study area

- a. Physical determinants of the basin
- b. Climate, hydrology and hydrogeology
- c. Socio-economic and cultural activities
- d. Management and planning (OMVS and OMVG)
- e. IWRM recent perspectives

### 2. Description of methodology

- a. Analyse of recent bibliography and state of the art on climate variability, climate change and risks, extreme events and climate modeling in West Africa
- b. Data and tools
  - i. Identification of data needs
    - Meteorological and hydrological
    - Topo-bathymetric and satellite images
    - Climate re-analysis
    - Socio-economics
    - Other data
  - ii. Data acquisition
    1. Archive data
    2. Ground data
    3. Re-analysis
  - iii. Tools
    - Climate variability analysis tools (Refran-CV, Kronostat, R, Xlstat...)
    - Satellite image analysis
    - Climate Change modelling
    - Risk analysis tools
- c. Detailed methodology for climate variability assessment
  - i. Descriptives analyses
    - Visual representation of data (basic and smoothed chronicle)
    - Preliminary analysis, summary results sheets
  - ii. Segmentation and homogenization procedures
    - Cutting of the series into homogeneous sub-series
    - Significance level
  - iii. Statistical tests
    - Evaluation of the validity of hypothesis (error risks)
    - Sort the large number of available tests
  - iv. Bayesian approach
    - Probabilistic framework combining several analysis levels
    - Regional analysis and uncertainty management
- d. Methodology for change and trends detection
  - i. Choosing test
  - ii. Trend regionalization
- e. Analysis steps

- i. Choice of stations
        - Criteria: time series (at least 40 years) with high quality data
        - Preliminary visits to hydrometric managers
        - Set of 200 hydrometric time series
      - ii. Local analysis of hydrological evolutions
        - Extraction of variables test variables (from daily flow chronicle)
        - Visualization of results: dialogue with managers for interpretation (metrology)
        - Reduced set of hydrometric time series
      - iii. Interpretation on the origins of evolutions
        - Regional analysis (significance and coherence)
        - Link with explanatory variables (rainfall, temperature, runoff aptitude)
    - f. Hydrological modeling and contribution of geospatial data
      - i. Definition and typology of hydrological models
      - ii. Geospatial data and distributed models
      - iii. Choice of the distributed hydrological model
      - iv. Design of modeling steps and application
- 3. The Western African database on Climate variability**
- a. Architecture of the database
  - b. Data sources and access
  - c. Data collection and sharing
  - d. Management of the database
- 4. Climate variability, climate change and trends analysis and modelling on Senegal and Gambia River Basins**
- a. Recent climate variability, climate change and trends
  - b. Climate change, extremes hydrologic events and consequences on hydrologic regimes
  - c. Study of the stationarity of hydrology extremes in the BFS and BFG
    - i. Stationarity as uncertainty
    - ii. Regional approach
  - d. Hydro-climatic risks management in non-stationary context
  - e. Proposal for risk management tools in a non-stationary context
- 5. Remote sensing, hydrological modeling and water resources evaluation in Senegal and Gambia hydrosystems**

## Presentation of the database

1. Inventory of existing data in the two river bodies: SRB and GRB
  - a. Hydrology, climate (rainfall and other parameters like temperatures, relative humidity, winds...), climatic re-analysis, global and regional models outputs
  - b. SRTM data
  - c. Satellite images
  - d. Vector maps
  - e. Socio-economic data
  - f. Social and health data
  - g. Environment
  - h. Parks and natural reserves
  - i. All other relevant data for both basins
2. Identification of data sources and development collection strategies
3. Architecture of the database
4. Data availability, issues
5. Challenges and possible solutions,
6. Overall planning of the work to be implemented

## Hydro-climatic data collection on SRB & GRB

Types de données	Informations sur les stations					
	Début obs.	Fin	Lat	long	Qualité	Observations
Débits	1903	2006	+	+	+	
Hauteurs	1903	2006	+	+	+	
Pluies	1905	2016	+	+	+	

The development of the database on SRB and GRB will firstly rely on the old ACEWATER1 database. At the Senegal State scale, the data will be completed through ANACIM<sup>1</sup> and DGPRE<sup>2</sup>. For other data from stations outside Senegal, the complement will be based on several sources:

- National focal point of IHP<sup>3</sup>;
  - Archives of IRD;
  - Partners like AGHYMET, OMVS<sup>4</sup>, OMVG<sup>5</sup>, ABN<sup>6</sup>, etc.;
- Other members of WANWATCE: KNUST, NWRI, 2iE.

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<sup>1</sup> Agence Nationale de l'Aviation Civile et de la Météorologie

<sup>2</sup> Direction de la Gestion et de la Planification des Ressources en Eau

<sup>3</sup> International Hydrological Programme

<sup>4</sup> Organisation pour la Mise en Valeur du fleuve Sénégal

<sup>5</sup> Organisation pour la Mise en Valeur de la Gambie

<sup>6</sup> Agence du Bassin du Niger