Water resources planning and management in Africa in the context of climate change

Challenges, initiatives and management tools

Abou AMANI, ing, Ph.D

Natural Science programme Specialist

UNESCO Accra office (Sierra Leone, Liberia, Cote d'ivoire, Ghana, Togo and Benin)

GHANA

E-mail: a.amani@unesco.org

Some realities

- Around 40% of the population in WA have not access to clean water (around 100 million inhabitants)
- 60% for sanitation
- More than 80% of deseases are water related diseases (Malaria, cholera, Guinea Worm,..;);
- Many countries are still struggling to cope to food insecurity;

- Less than 4% of renewable WR are mobilized in WA;
- Only around 10% of irriguable lands are irriguated in WA;
- Only 16% of hydro-power potential are mobilized.

Ecowas water policy (2007)

Importance of climate in WA

Around 70% of the population in WA are rural population with agriculture and livestock as main activities;

Agriculture in WA is essentially rainfed and is therefore highly vulnerable with climate fluctuations;

Livestock is greatly sensitive to the availability of Biomass and water resources;

The primary Sector contributes to around 35% of the GDP of many countries in WA and is an important factor of economic growth.

Rainy season is an important factor in the region

IPCC(2001, 2007) have qualified Africa as the most vulnerable continent to climate change

Plan of the presentation

- Characteristics of WR in WA
- Climate Variability and its impacts
- Climate change / Global change and its impacts
- Africa Water Vision 2025
- Research priorities
- Institutionnal interventions
- Operational and Scientific interventions
- Management Tools

Water resources in Africa

Surface water

Concentrated within few river basins

cooperation between riparian countries is needed

groundwater

repartition depends on the hydrogeology

few shared hydrogeological basins

cooperation is also needed

Renewable water resources in WA

UNWWDR2, AQUASAT, 2005	M3/capta/year
Benin	3820
Burkina	930
Cape Verde	630
Cote d'Ivoire	4790
Gambia	5470
Ghana	2490
Guinea	26220
Guinea-bissau	20160
Liberia	66530
Mali	7460
Mauritania	3830
Niger	2710
Nigeria	2250
Senegal	3810
Serra Leone	30960
Togo	2930
Chad	4860

In 2025, only by the effect of the population growth,

Six countries will be in scarcity or stress situation and two countries will not be far from the stress threshold

Rainfall variability in West Africa

Seasonal variability

- **Around 80% of rainfall during JAS in Sahel**

Great inter-annual variability

- **Break in annual cumul time series,**
- **Nord-south shifting of annual isohyets**
- **decrease of number of rainy days,**
- **Increasing of dry spell**
- **Great variability of onset**

Great spatial variability

Impacts on water resources (1/2)

Water resources concentrated within 3-4 months

Great inter-annual variability

decrease of water availability(40-60%)

great reduction of wetland areas

Decrease of groundwater table

Impacts on water resources (2/2)

Increase for small and localized systems

Increase of runoff coefficient and discharge due to great modification of land use land cover

Increase of aquifer water table

due to land use land cover changes and recharge process

Future?

What is the future evolution?

From IPCC TAR and FAR.

- **Temperature global increase 1.4-5,8°C**
- **Increasing of Maxi and Mini temperature**
- **Reinforcement of the hydrological cycle and the extremes (droughts and floods)**
- **Sea level rise 9-88 cm**

- **Global increase of rainfall, spatial variation not clear, still models are not consistent in many parts of Africa and not capture very well the regime**

IMPACTS

- Impacts on water resources
- Impacts on agriculture
- Aggravation of coastal erosion
- Flooding of coastal low areas
- Degradation of some ecosystems
- Reinforcement of extremes (too much or too little water)

Adaptation: A necessity

- **Climate change is a reality**
- **Ecosystems continue to be degradated**
- **Great vulnerability of the population vis-à-vis climate change;**
- **Different water uses and more competion with the increasing of populuatin needs**

Integrated Water resources Management (IWRM) a systematic process for the sustainable development, allocation and monitoring of water resource use in the context of social, economic and environmental objectives.

Africa Water Vision 2025

AN AFRICA WHERE THERE IS AN EQUITABLE AND SUSTAINABLE USE AND MANAGEMENT OF WATER RESOURCES FOR POVERTY ALLEVIATION, SOCIOECONOMIC DEVELOPMENT, REGIONAL COOPERATION, AND THE ENVIRONMENT.

A vision

1. **There is sustainable access to a safe and adequate water supply and sanitation to meet the basic needs of all;**
2. **Water inputs towards food and energy security are readily available;**
3. **Water for sustaining ecosystems and biodiversity is adequate in quantity and quality;**
4. **Water-resources institutions have been reformed to create an enabling environment for effective and integrated management of water in national and trans-boundary water basins, including management at the lowest appropriate level;**
5. **Water basins serve as a basis for regional cooperation and development, and are treated as natural assets for all within such basins;**

A vision

6. **There is an adequate number of motivated and highly skilled water professionals;**
7. **There is an effective and financially sustainable system for data collection, assessment and dissemination for national and trans-boundary water basins;**
8. **There are effective and sustainable strategies for addressing natural and man-made problems affecting water resources, including climate variability and change;**
9. **Water is financed and priced to promote equity, efficiency, and sustainability;**
10. **There is political will, public awareness and commitment among all for sustainable management of water resources, including the mainstreaming of gender issues and youth concerns and the use of participatory approaches.**

Research priorities

- **Improvement of knowledge on climate and its impacts (Ex: Programme AMMA);**
- **Improvement of knowledge on the water resources and particularly on groundwater;**
- **Tools for decision making for sustainable management of water resources;**
- **Promotion of IWRM and ecosystem approach for the management of water resources and wetlands;**
- **Identification, promotion and diffusion of technologies and appropriate measures for adaptation to climate change;**

Institutional initiatives

- AMCOW (Committee of African Ministers in charge of Water)
- African Water Facility hosted by African Development Bank
- African Commisssion on Groundwater
- African water week
- Creation of River basin organizations (OMVS, OMVG, NBA, VBA, LCBC, ..), RAOB
- Creation of Water Coordination Unit for ECOWAS and SADC
- UN-Water / Africa
- National, sub-regional water partnerships (IWRM)

Operational and research initiatives

- **WHYCOS (SADC, IGAD, CONGO, NIGER, VOLTA, LCBC, OMVS);**
- **FORA on seasonal forecast (PRESAO, PRESAC, South, East, North)**
- **FRIEND for hydrology and water resources (SADC, AOC, Nile)**
- **ISARM (SADC, AOC), GRAPHIC, TIGER**
- **RIPIESCA, ACCA**
- **AMMA: research on African Monsoon and its impacts**

Some Tools

TDA/SAP for IWRM

- **IDF curves and Flood frequency Analysis**

Need to take into account climate change dimension

- **Early Warning Systems**
  - **Flood**
  - **Drought : Africa Drought Monitor**
  - **Seasonal forecast : PRESAO**

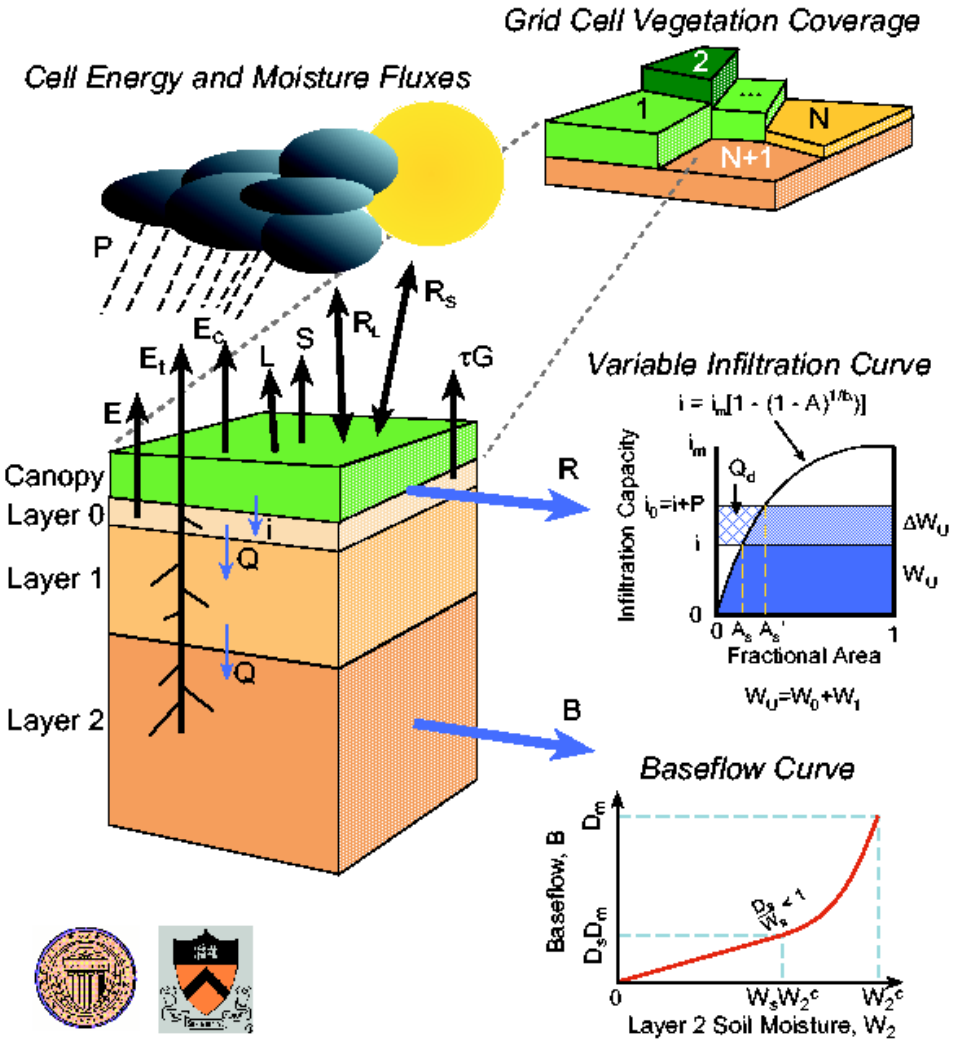
Find more

AMMA (http://www.ird.ne/ammanet)

PRESAO (http://www.acmad.ne;
http://www.agrhymet.ne) ;

WWDR (http://www.unesco.org/water) ;

Variable Infiltration Capacity (VIC) Macroscale Hydrologic Model



VIC Land Surface Model
SVATS

Input Variables

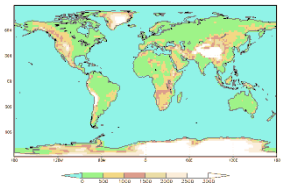
Rainfall
Temperature
Windspeed
Radiation
Pressure

Spatial resolution
1° by 1°

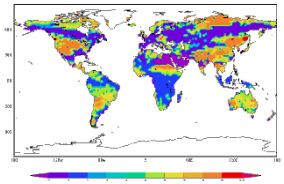
Time steps
3 h, daily

Input parameters

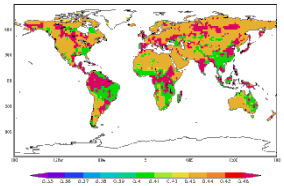
Elevation



Vegetation



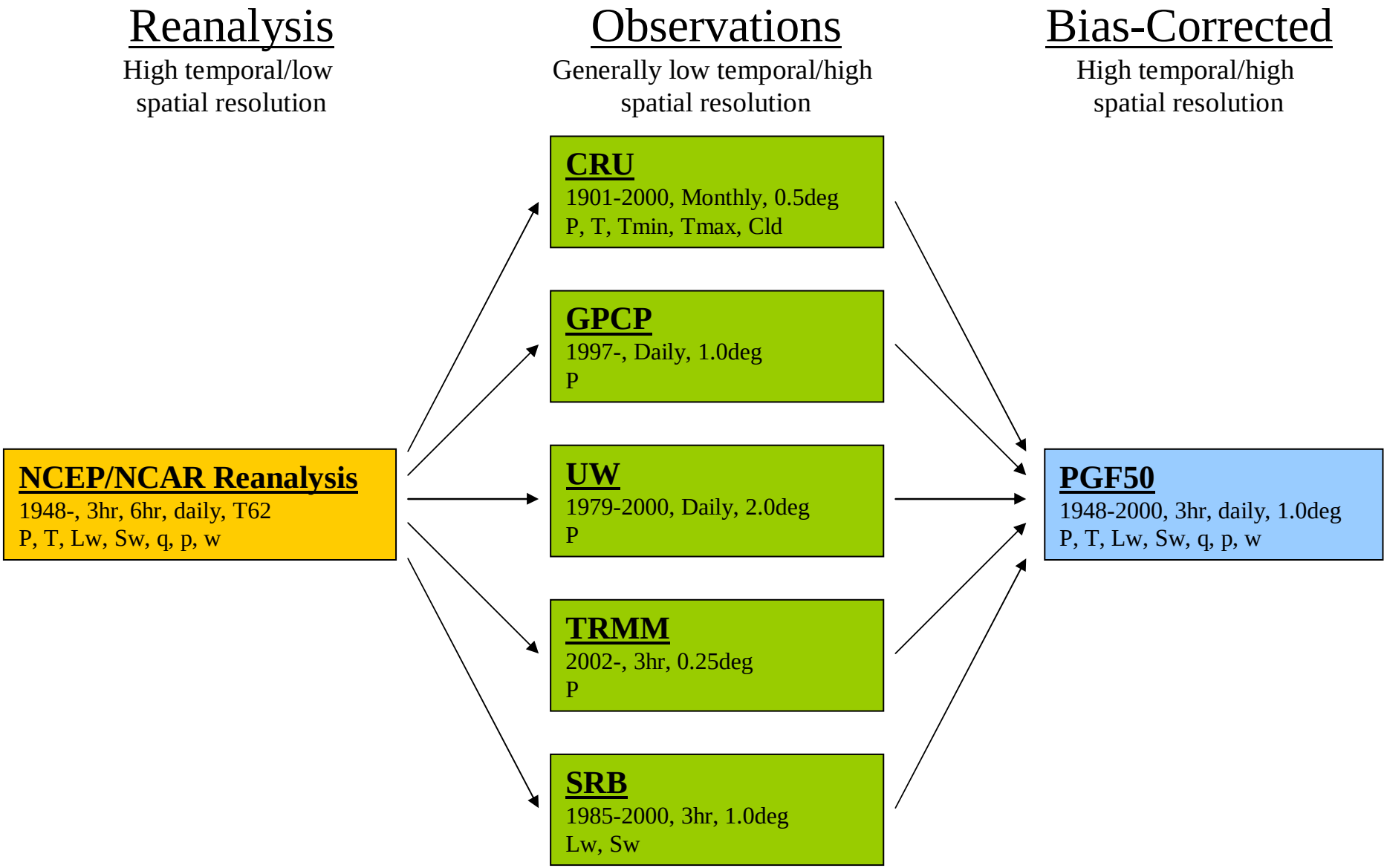
Soil porosity



Output variables

Soil moisture (three layers)
evapotranspiration
discharge

Global Forcing Dataset



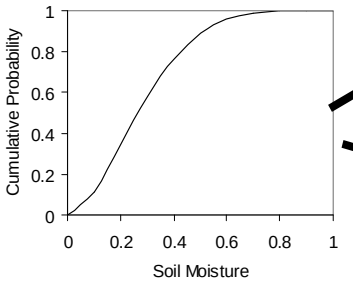
Development of Global Real-Time Drought Monitoring

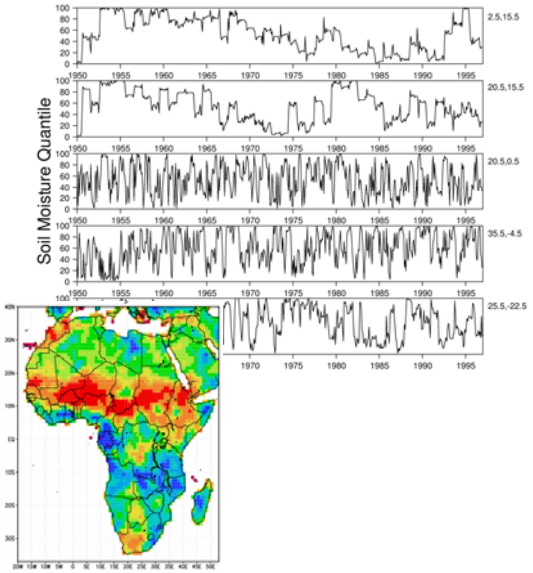
1) Retrospective Simulation -- DONE

2) Calculate Soil Moisture Index -- DONE

3) Historical Drought Analysis -- DONE

Historic soil moisture

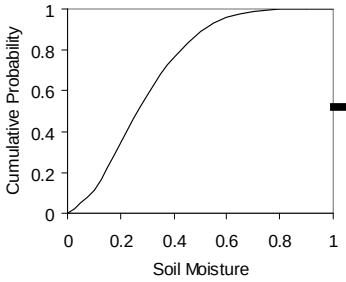


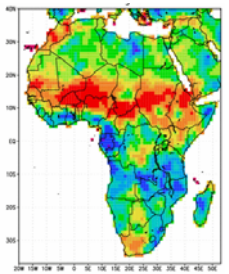


4) Real-time Drought Analysis – NEED REAL TIME FORCINGS

Realtime soil moisture

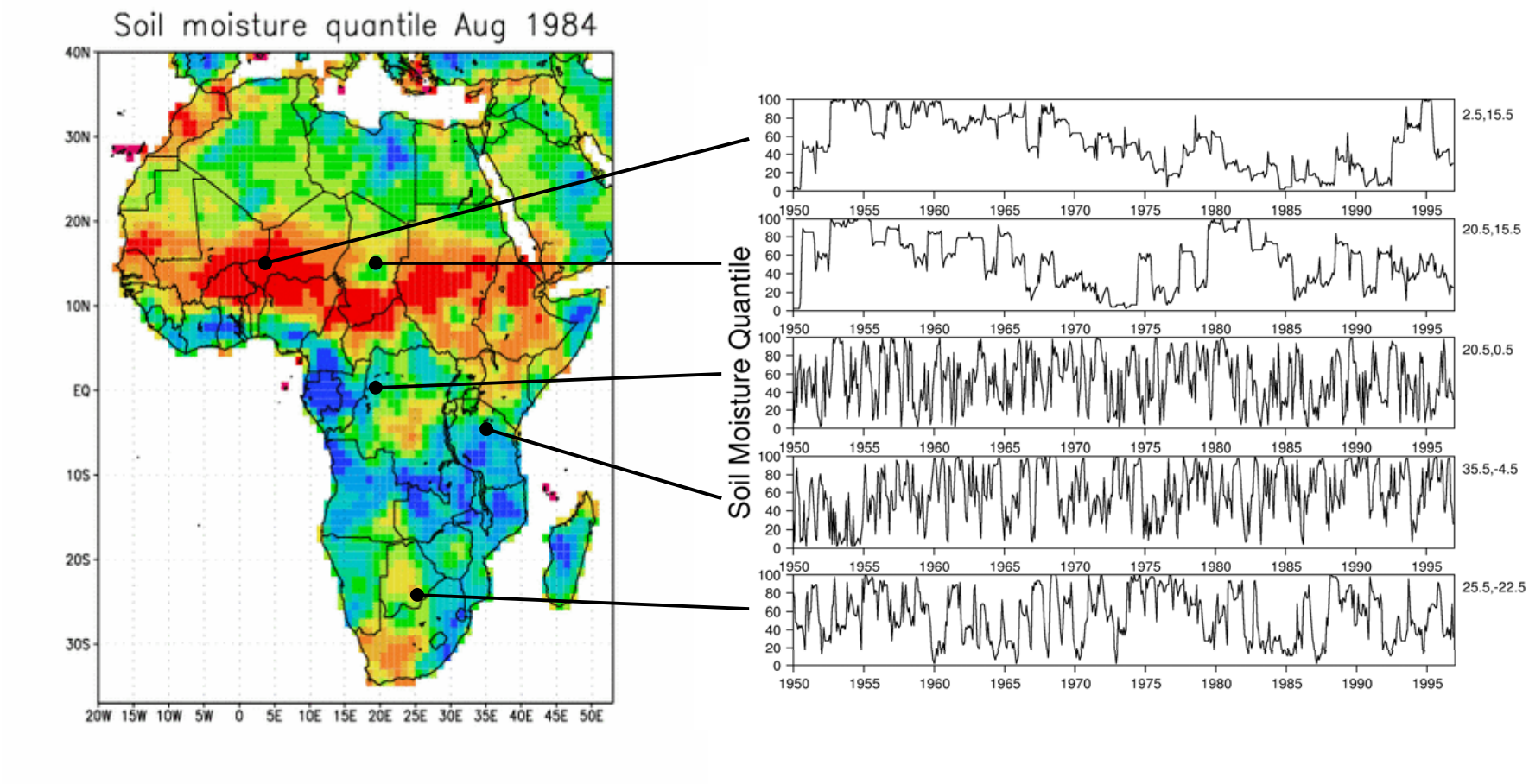
- **GTS observations**
- **ECMWF analysis**
- **Satellite observations (NASA, ESA, JAXA)**





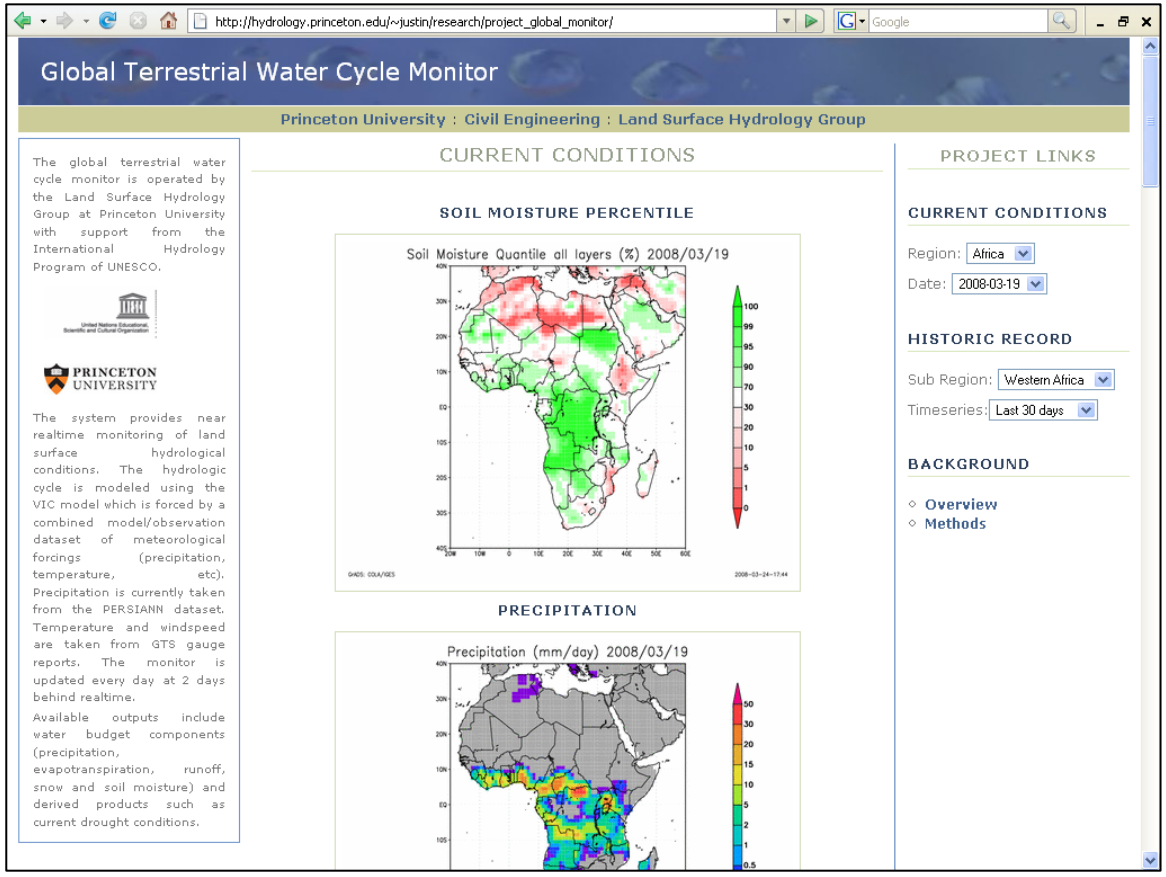
(PERSIANN dataset)

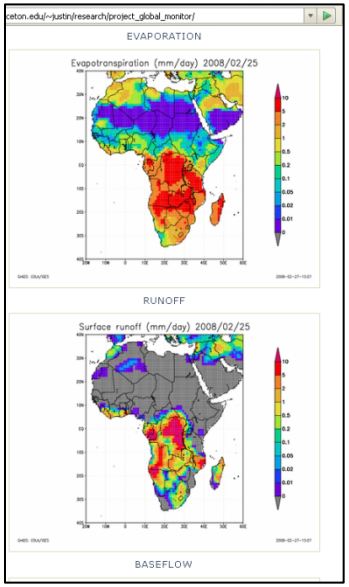
Focus on African Drought

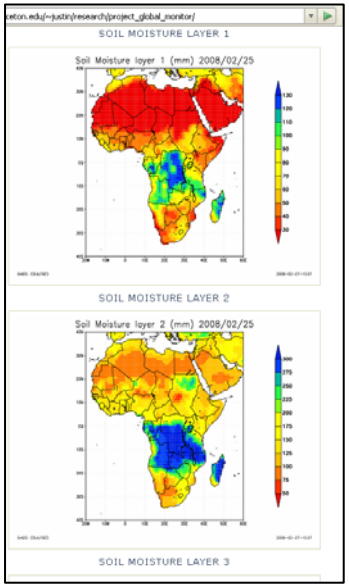


Water Cycle and Drought Monitoring over Africa

http://hydrology.princeton.edu/monitor

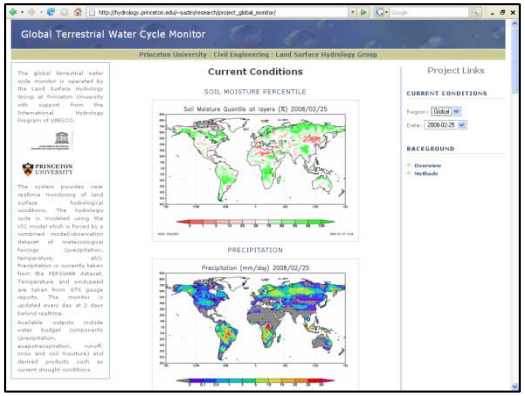






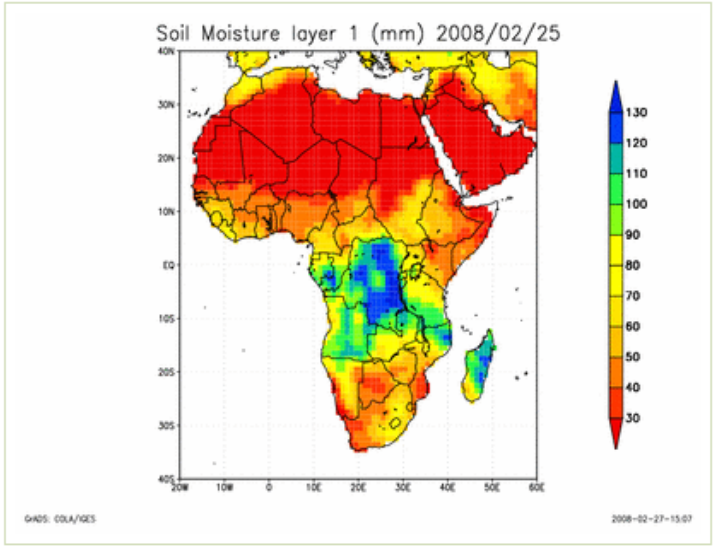
Terrestrial water cycle (evaporation, runoff, soil moisture, snow) simulated using the VIC land surface model, forced by observed and remotely sensed precipitation and temperature

We are also monitoring globally…

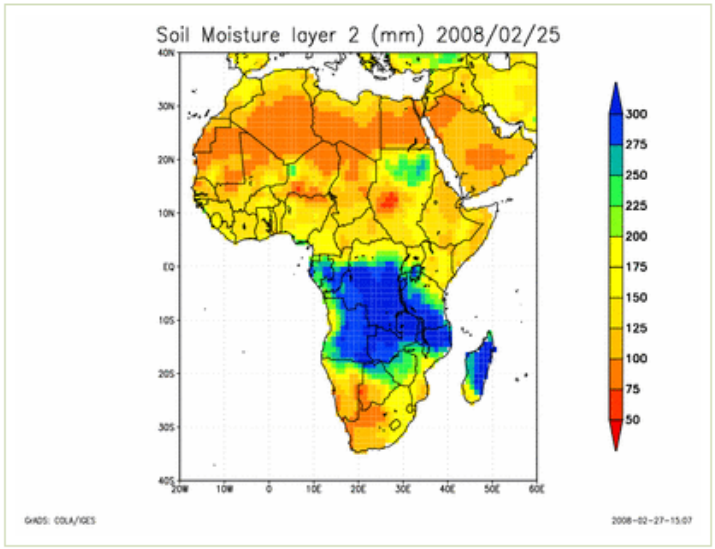


ceton.edu/~justin/research/project_global_monitor/

SOIL MOISTURE LAYER 1



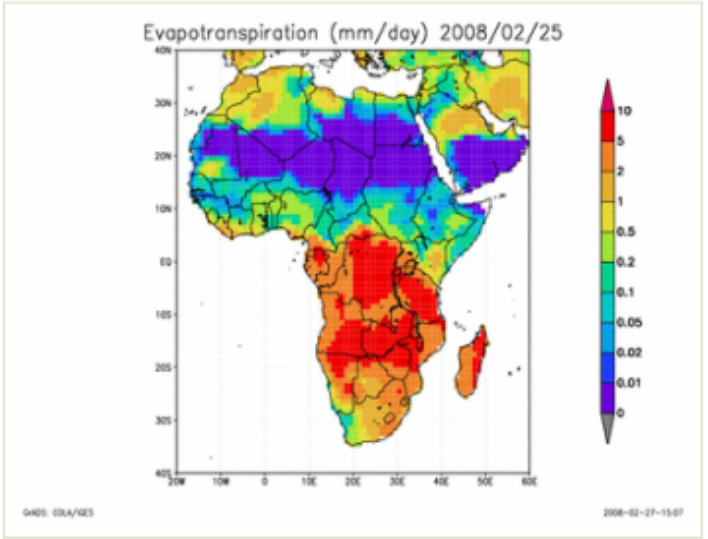
SOIL MOISTURE LAYER 2



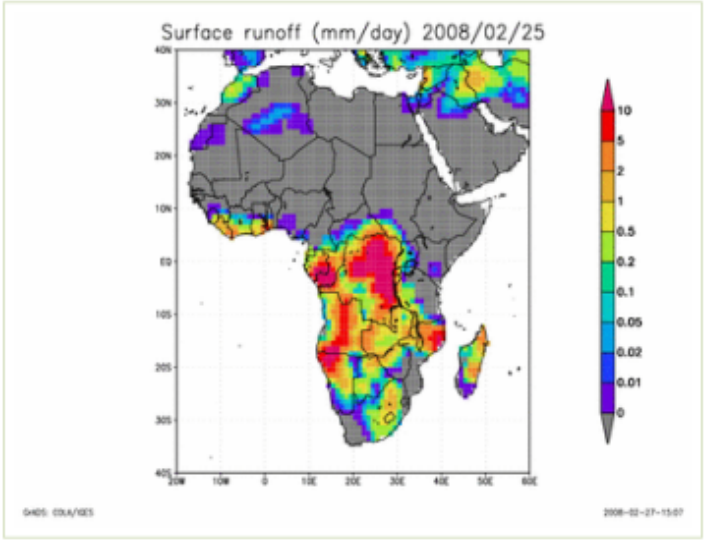
SOIL MOISTURE LAYER 3

ceton.edu/~justin/research/project_global_monitor/

EVAPORATION



RUNOFF



BASEFLOW

TESTS AND VALIDATION

UNESCO-IHP and UNIVERSITY OF PRINCETON will work with AGRHYMET and NBA for the test and validation of the different products

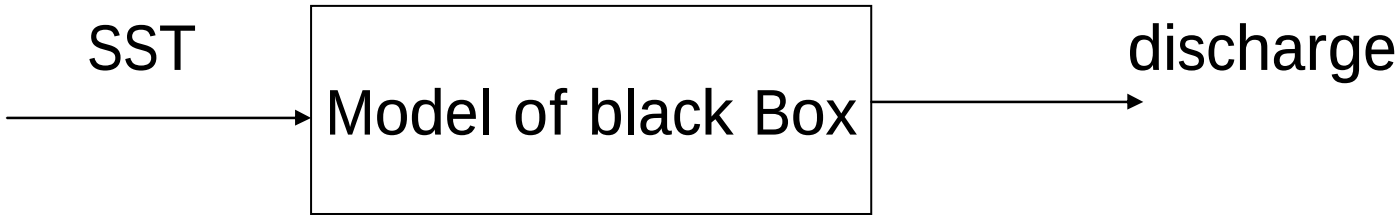
- **Datasets used in the region compared to the observations (AGRHYMET Network, EPSAT)**

- **Coherence of soil moisture pattern (comparison with some DHC ouputs)**

- **Comparison with discharge indexes of main rivers in the sub-region**

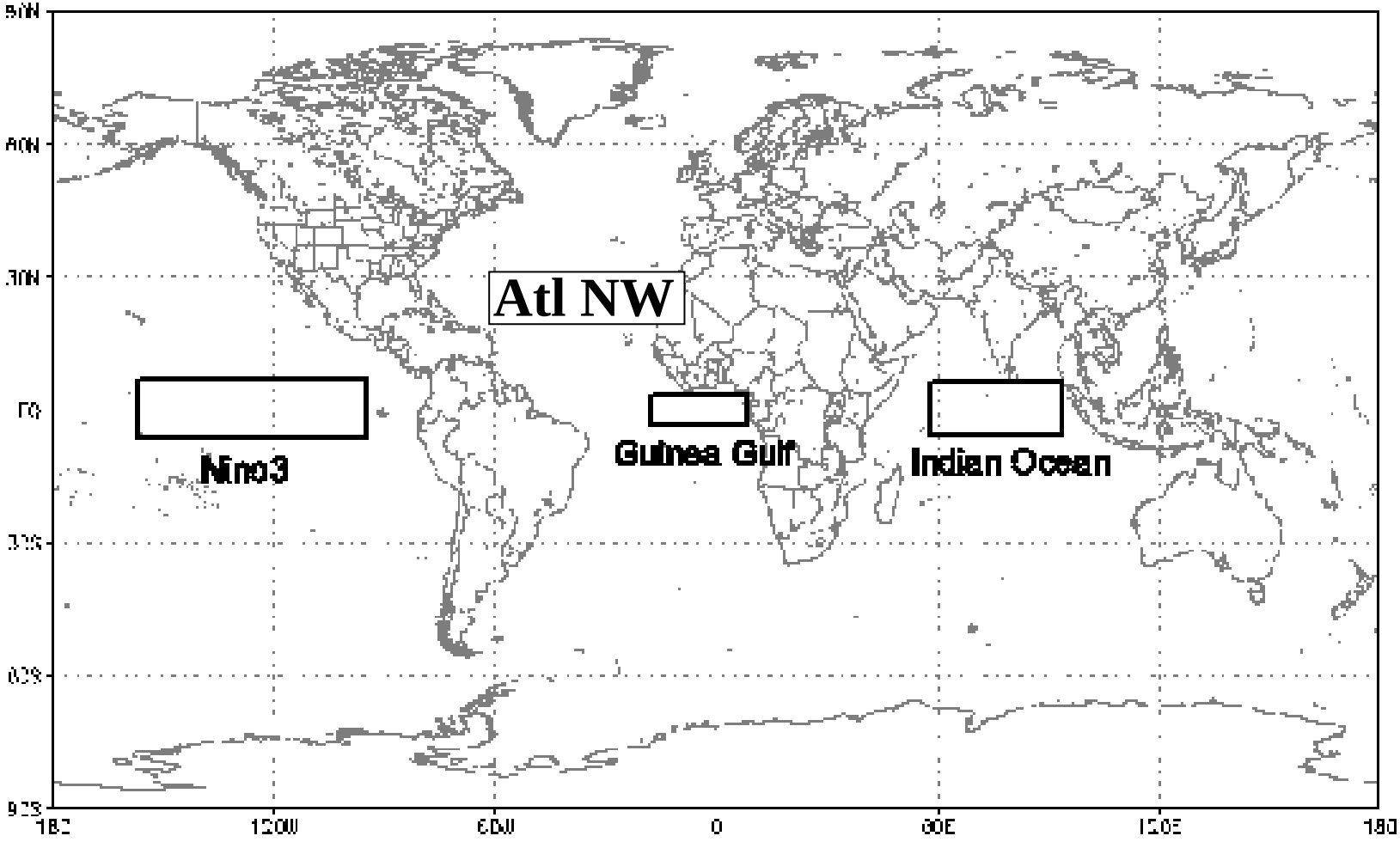
Could be used as a complementary tool for the monitoring of the rainy season by AGRHYMET

Methodology for the seasonal forecast of discharge



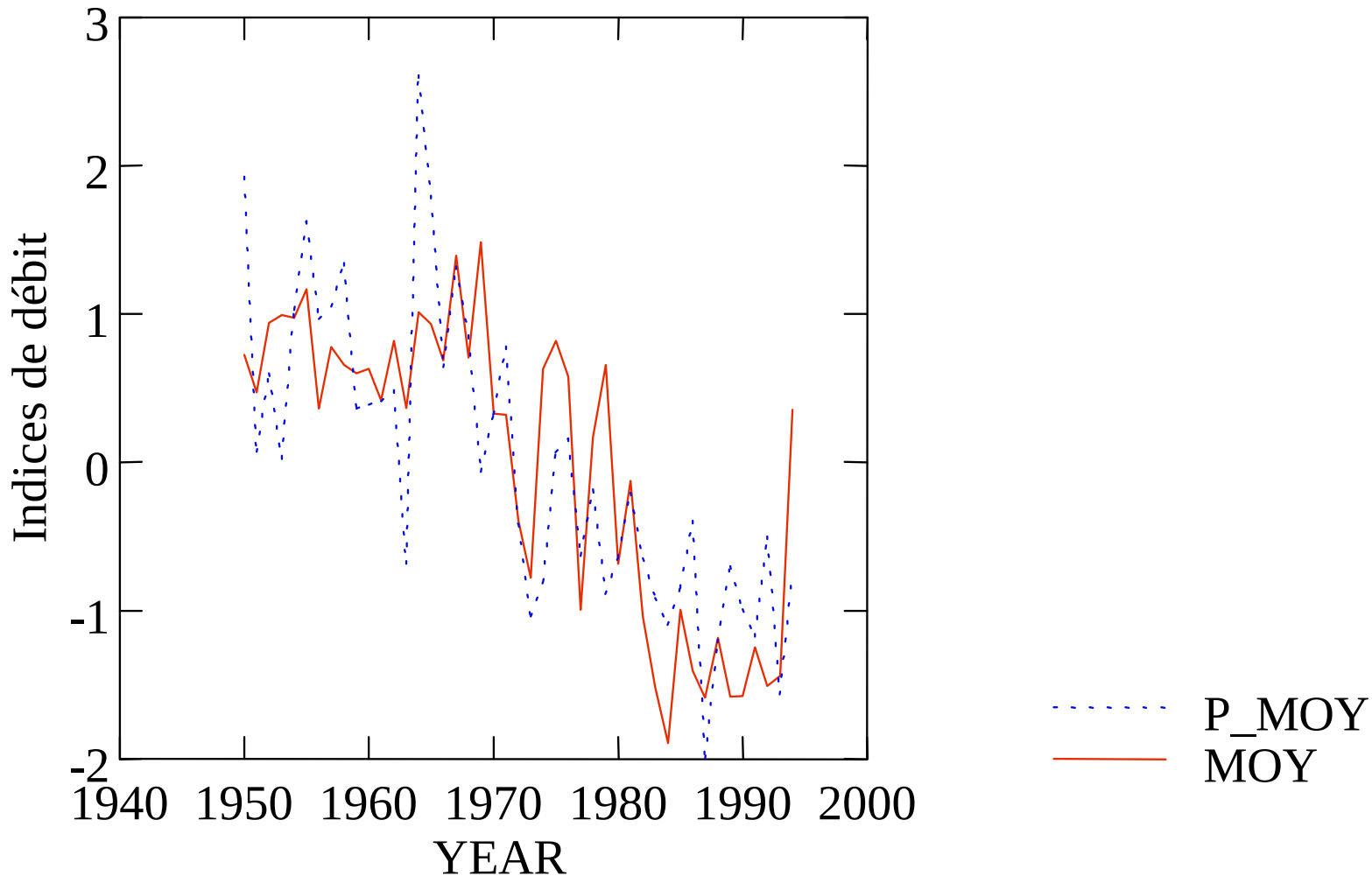
Search for a direct statistical link between SST and discharge

Oceanic areas having an influence the West Africa Climate



NIGER at NIAMEY:

Compared discharge indexes observed and forecasted



Steps for the seasonal forecast

Rank the index values from the highest to the smallest and divide the series in three categories: high, medium and low hydraulicity.

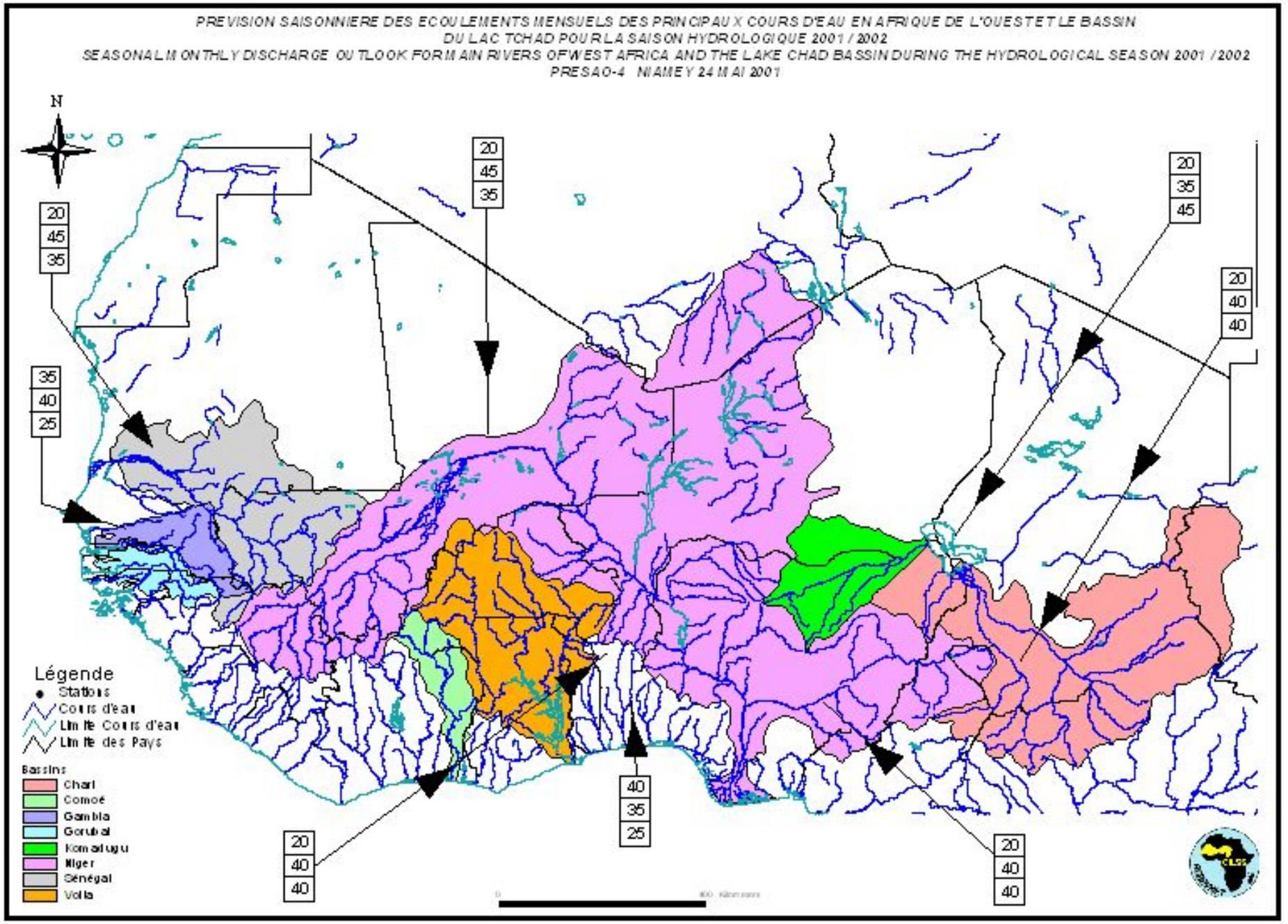
Above normal
normal
Below normal

-Based on the forecast index, find the category of the forecast

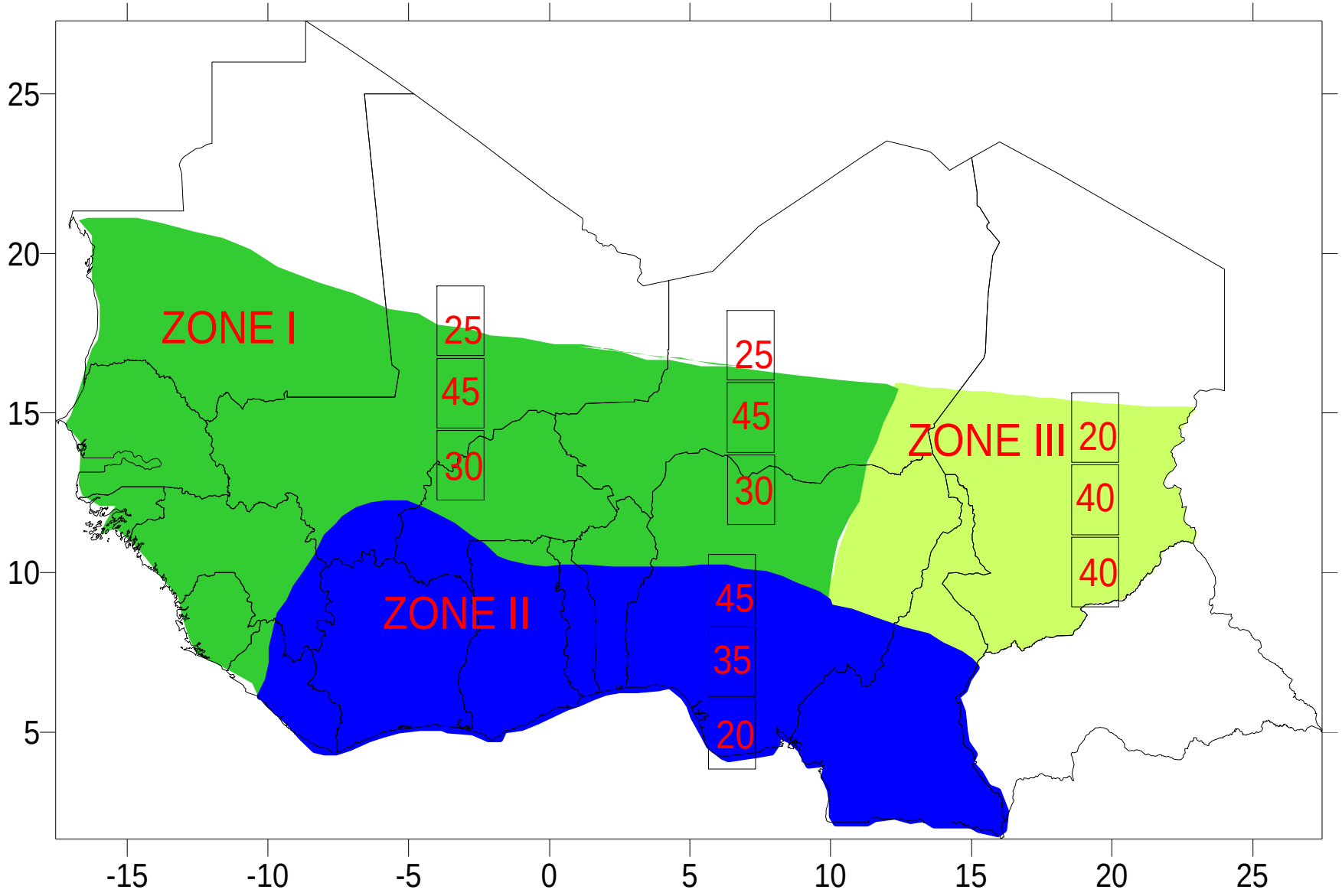
PREVISION SAISONNIERE DES ECOULEMENTS MENSUELS DES PRINCIPAUX COURS D'EAU EN AFRIQUE DE L'OUEST ET LE BASSIN DU LAC TCHAD POUR LA SAISON HYDROLOGIQUE 2001 / 2002

SEASONAL MONTHLY DISCHARGE OUTLOOK FOR MAIN RIVERS OF WEST AFRICA AND THE LAKE CHAD BASSIN DURING THE HYDROLOGICAL SEASON 2001 / 2002

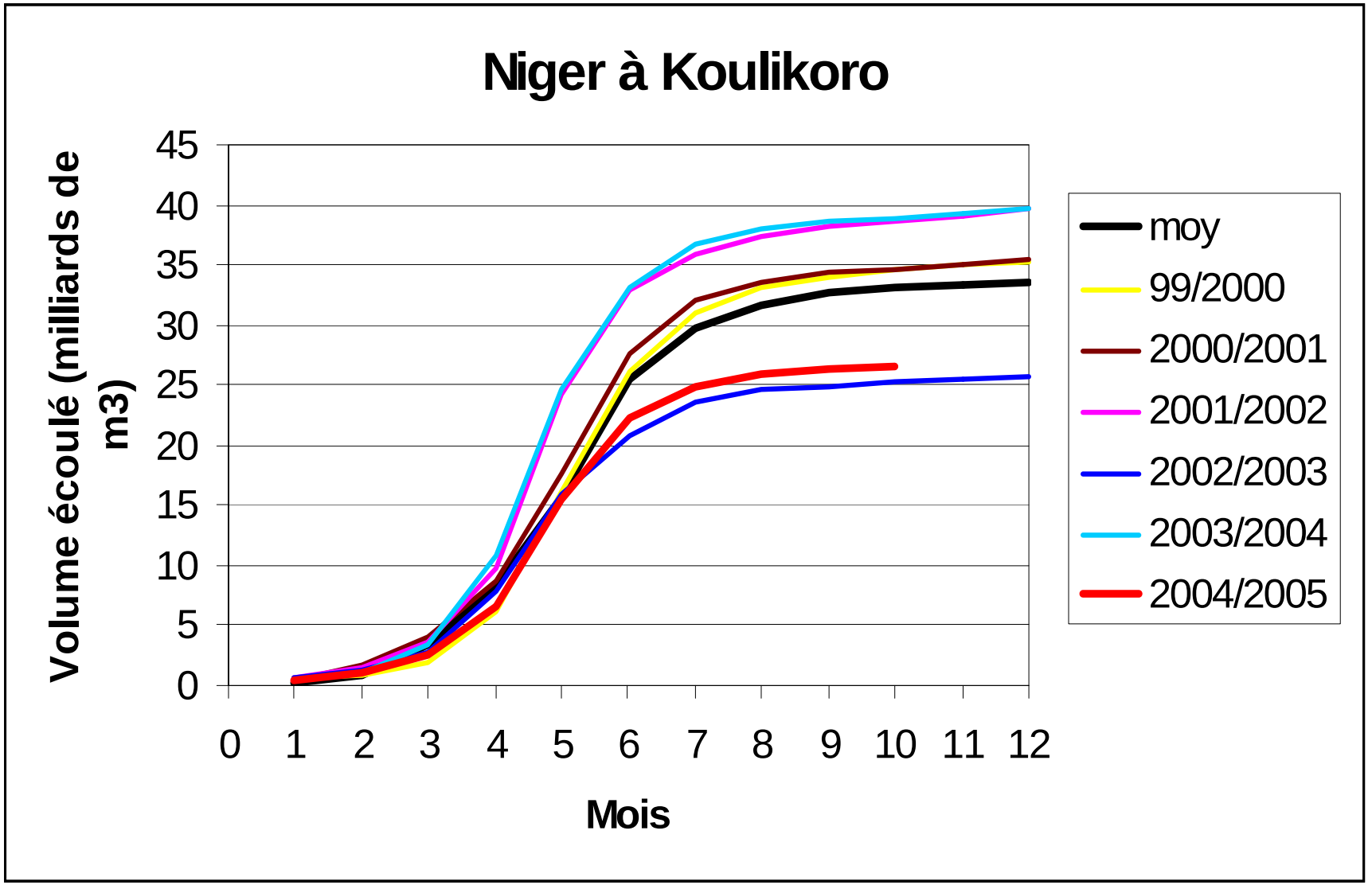
PRESAO-4 NIAMEY 24 MAI 2001



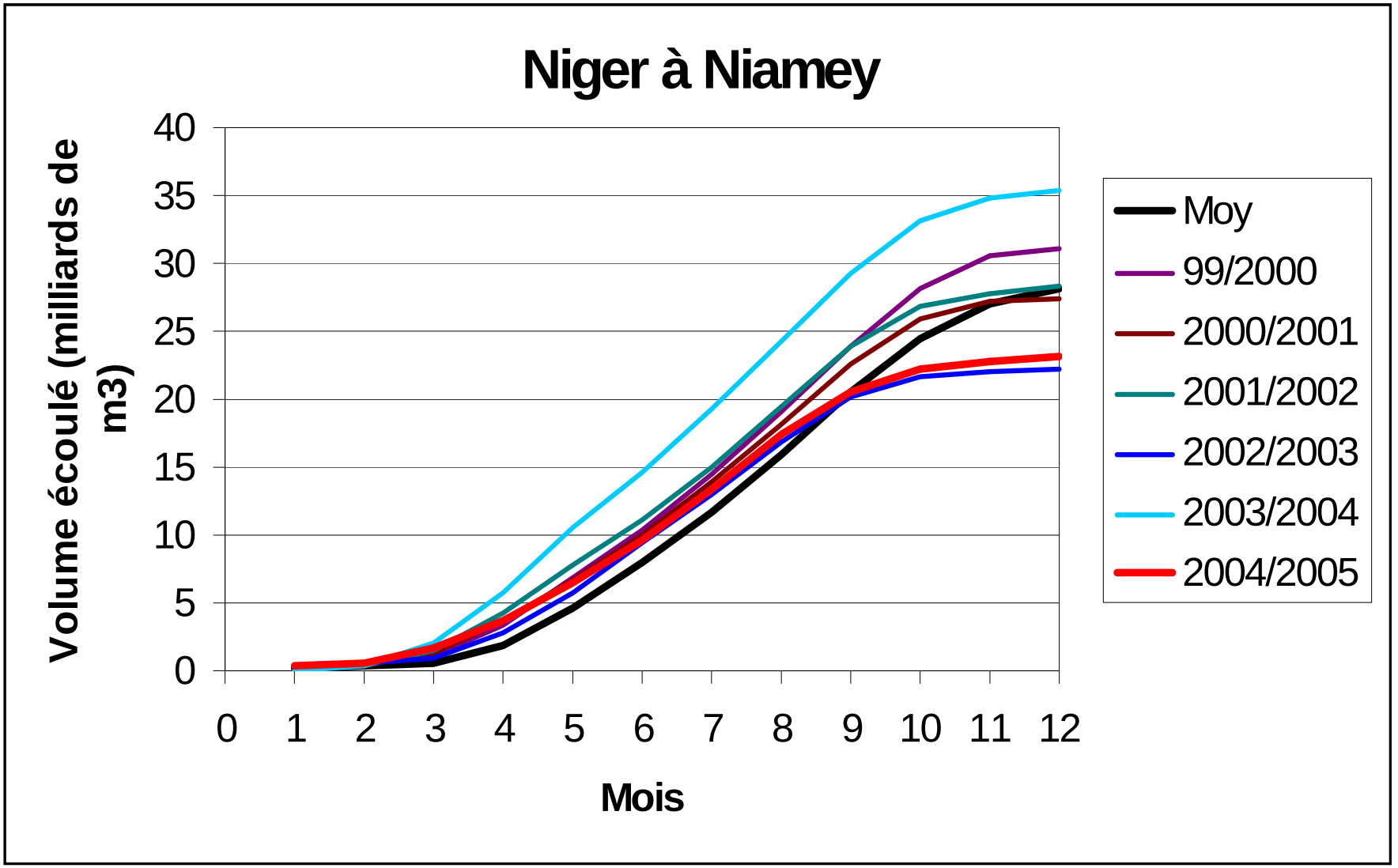
PREVISION SAISONNIERE DES PLUIES EN AFRIQUE DE L'OUEST, LE TCHAD ET LE CAMEROUN
JUILLET- AOUT- SEPTEMBRE 2002



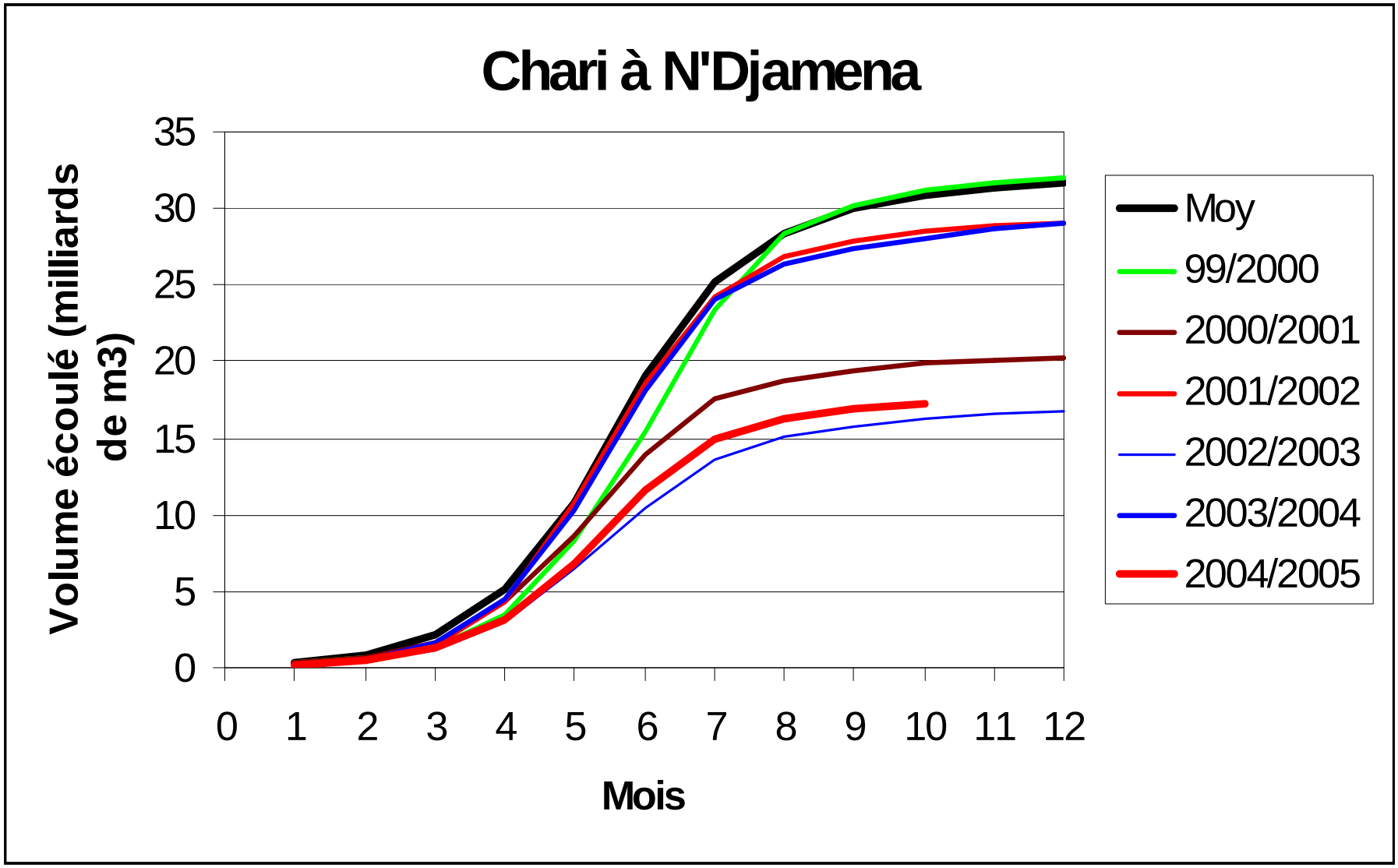
HAUT BASSIN DU NIGER



NIGER MOYEN


Niger à Niamey
Volume écoulé (milliards de m3)
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12
Mois
Moy
99/2000
2000/2001
2001/2002
2002/2003
2003/2004
2004/2005

BASSIN DU LAC TCHAD



Validation of the forecast for six years

Quality of the forecast by basin

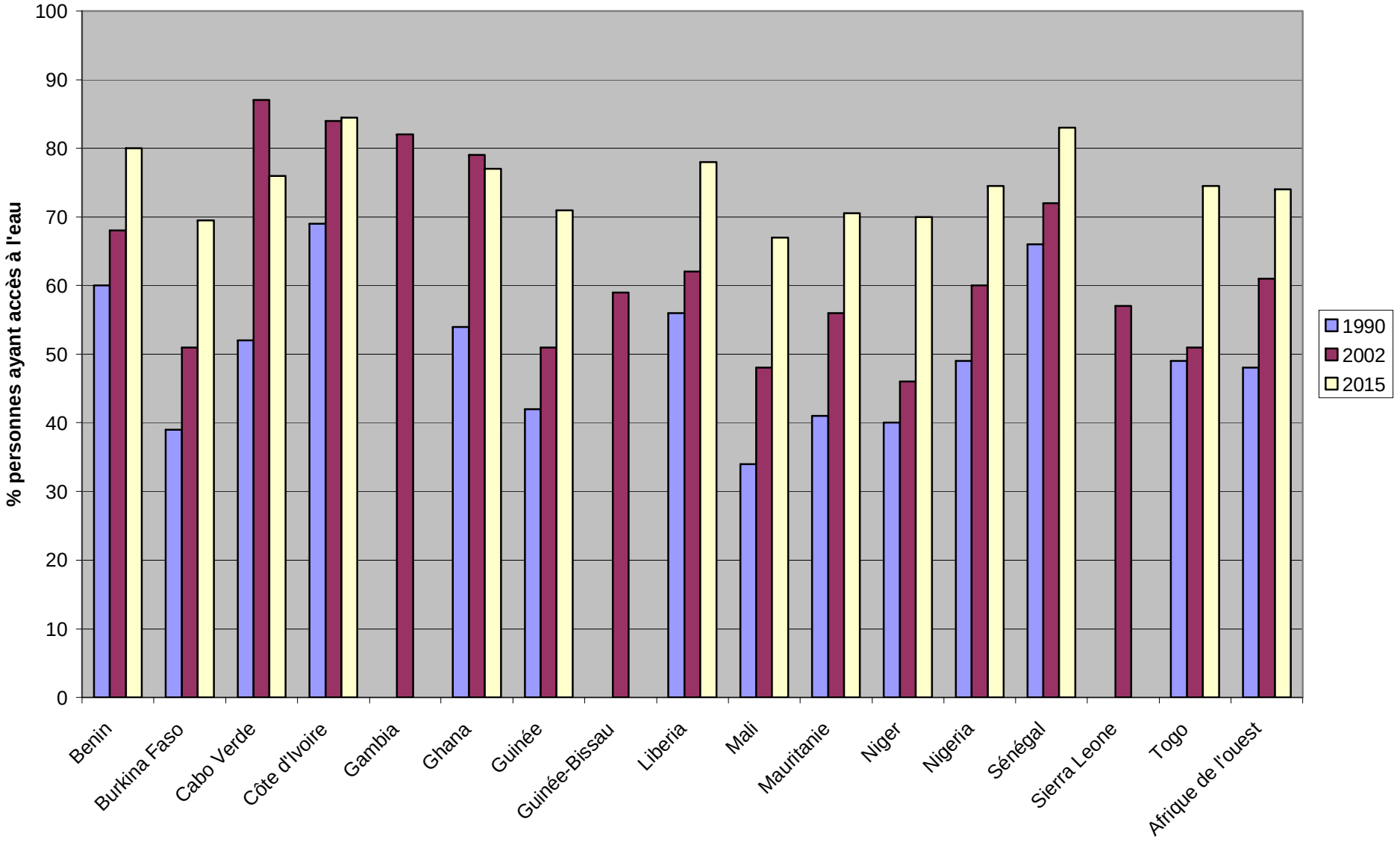
Niger Moyen (5/6)
Bassin du Sénégal (4/6)
Bassin du lac Tchad (4/6)
Haut bassin du Niger (3/6)

Quality of the forecast by year

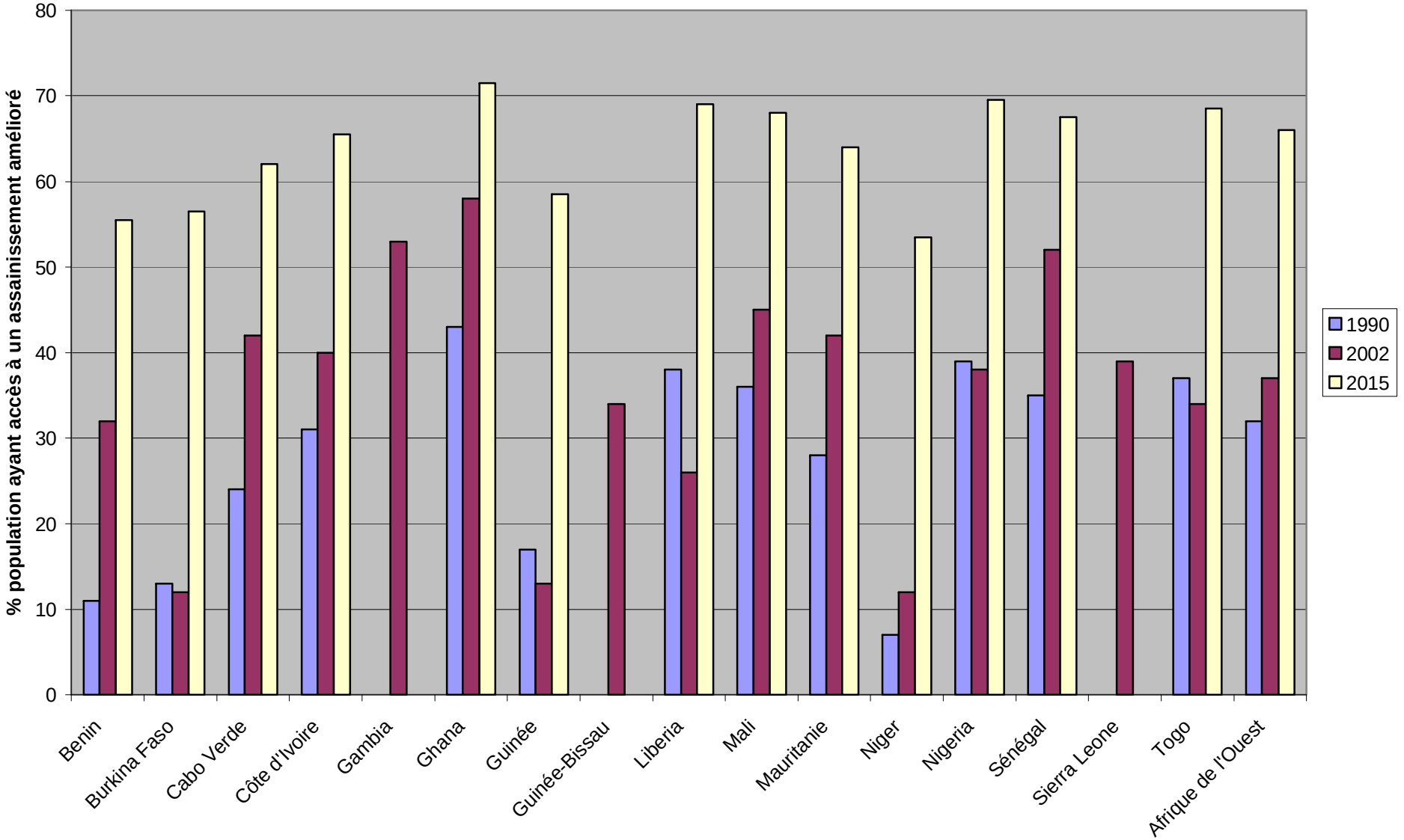
2000 et 2001 (100%)
2002 (75%)
1999 et 2003 (50%)
2004 (25%)

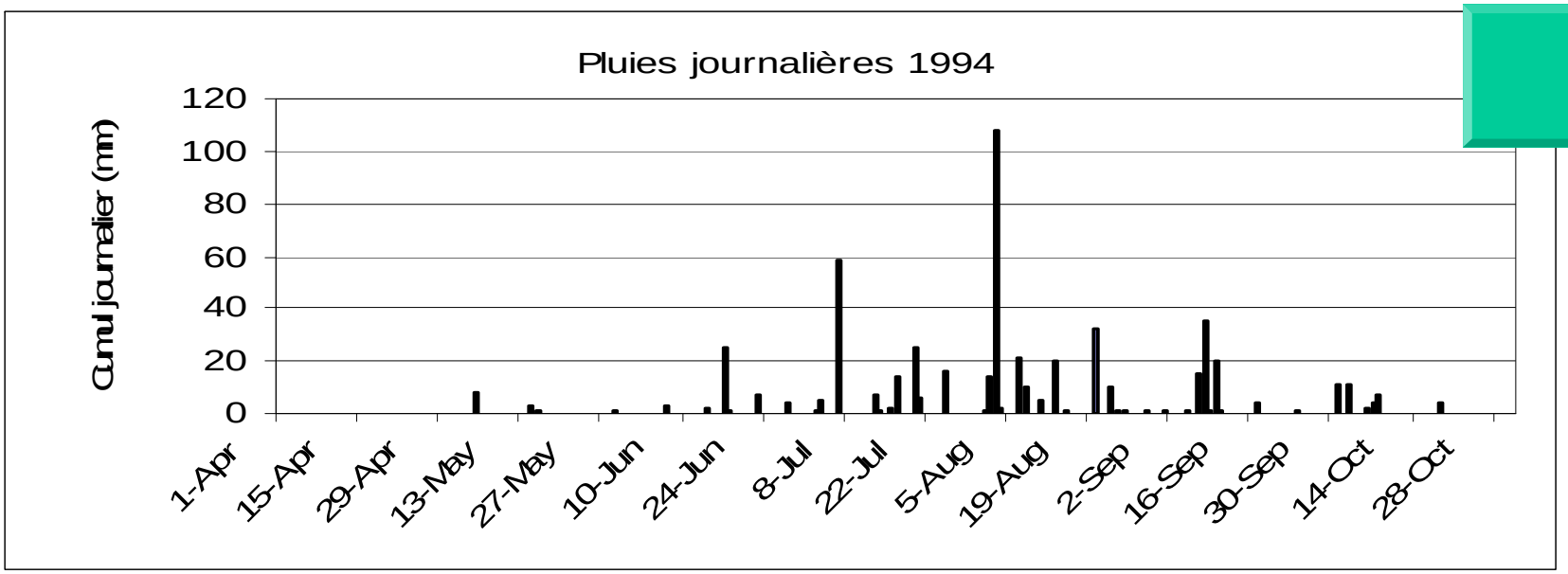
Globally (16/24)
67%

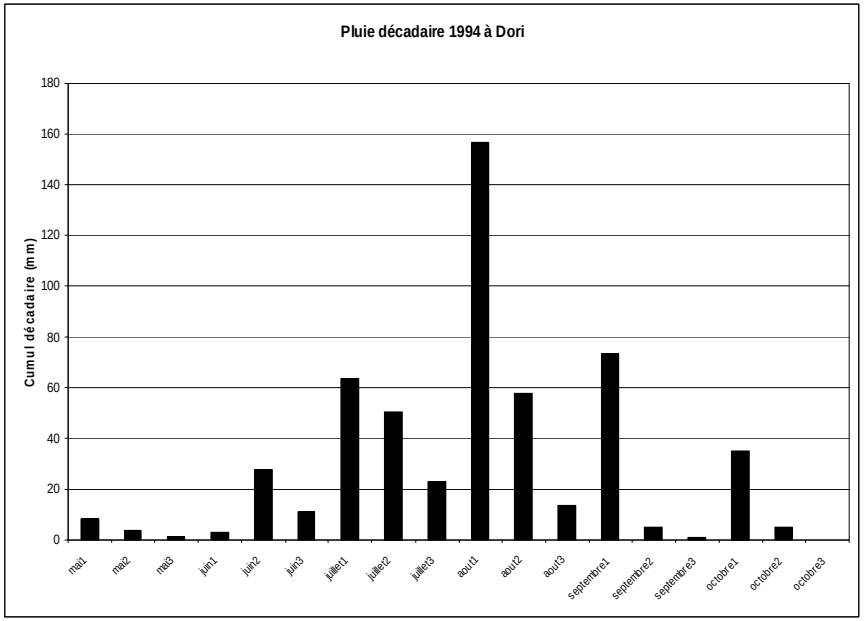
Percentage of access to clean water (2002)

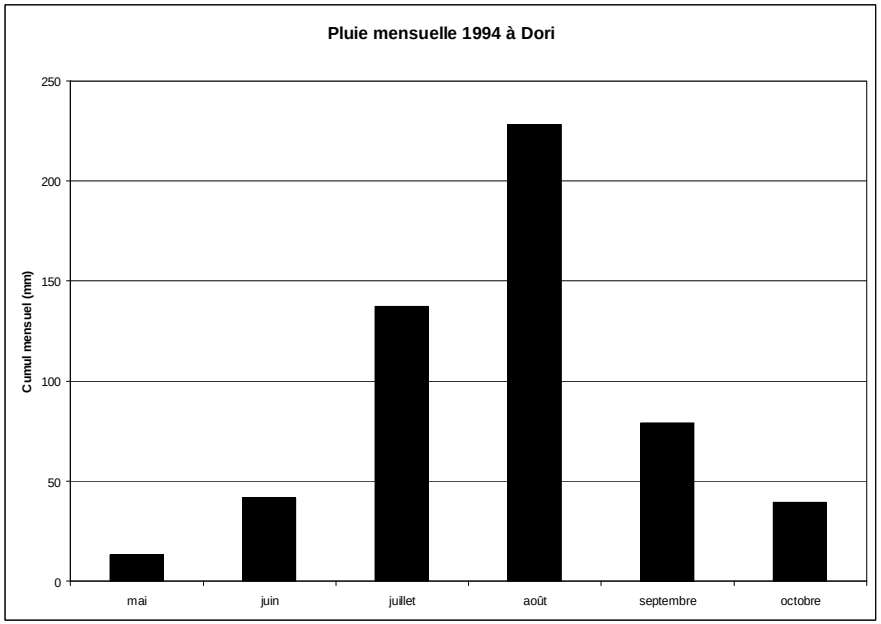


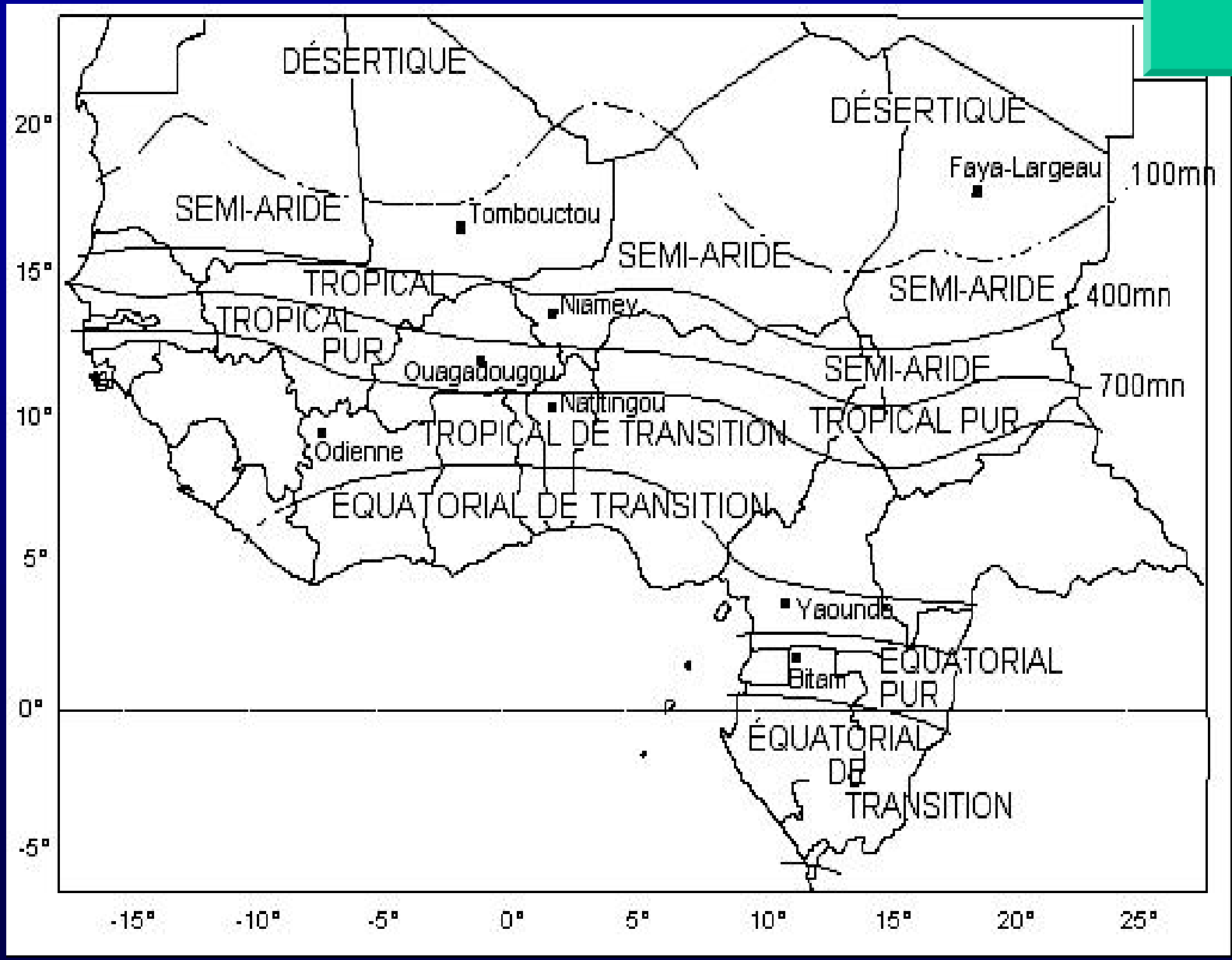
Percentage of access to sanitation(2002)

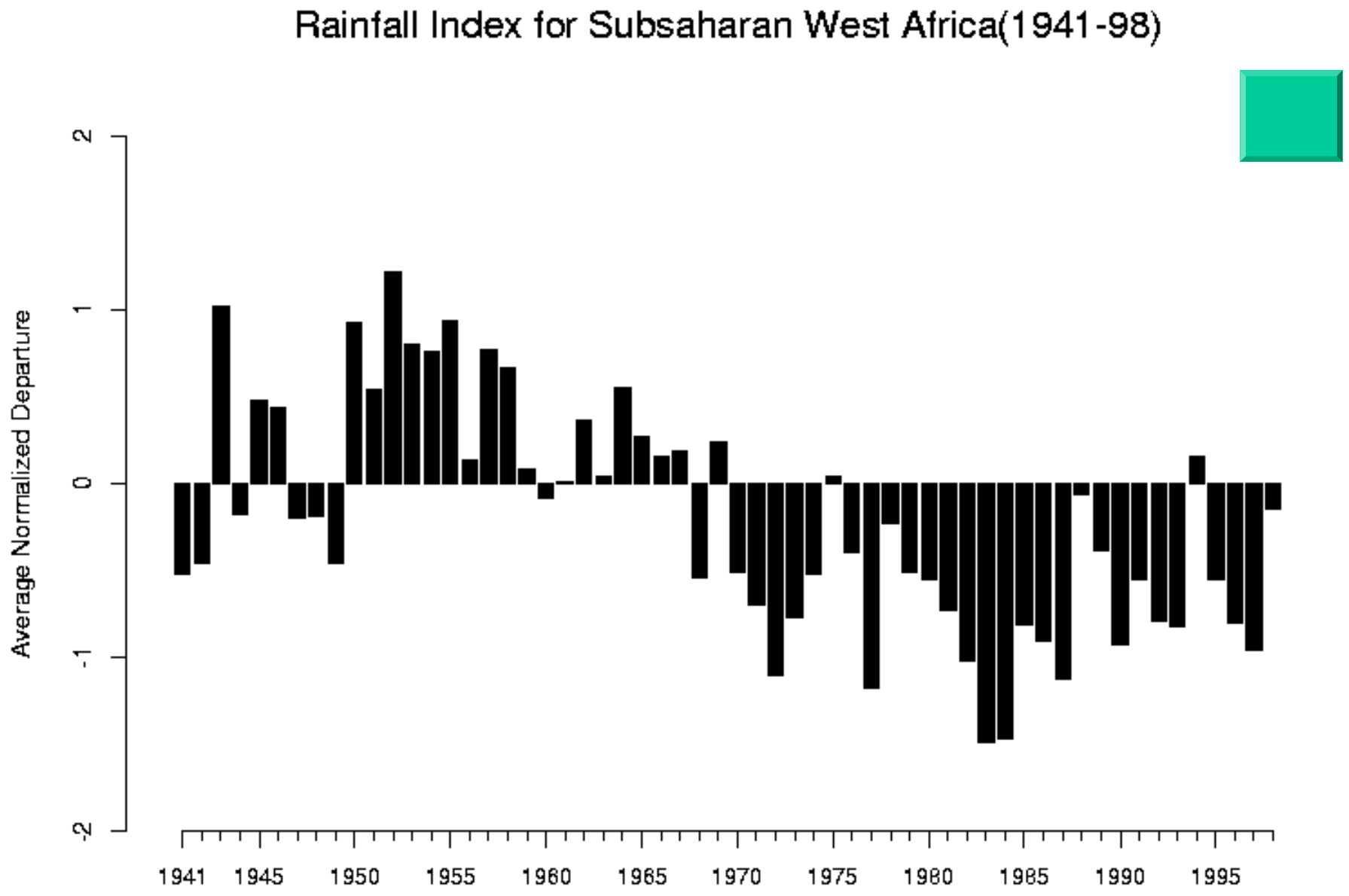



Pluies journalières 1994
Cumul journalier (mm)
120
100
80
60
40
20
0
1-Apr
15-Apr
29-Apr
13-May
27-May
10-Jun
24-Jun
8-Jul
22-Jul
5-Aug
19-Aug
2-Sep
16-Sep
30-Sep
14-Oct
28-Oct


Pluie décadaire 1994 à Dori
Cumul décadaire (mm)
180
160
140
120
100
80
60
40
20
0
mai1
mai2
mai3
juin1
juin2
juin3
juillet1
juillet2
juillet3
aout1
aout2
aout3
septembre1
septembre2
septembre3
octobre1
octobre2
octobre3


Pluie mensuelle 1994 à Dori
Cumul mensuel (mm)
250
200
150
100
50
0
mai
juin
juillet
août
septembre
octobre


DÉSERTIQUE
DÉSERTIQUE
Faya-Largeau
100mn
SEMI-ARIDE
Tombouctou
SEMI-ARIDE
TROPICAL
SEMI-ARIDE
400mn
Niamey
TROPICAL
PUR
Ouagadougou
SEMI-ARIDE
700mn
Natitingou
TROPICAL PUR
TROPICAL DE TRANSITION
Odienne
ÉQUATORIAL DE TRANSITION
Yaounde
ÉQUATORIAL
PUR
Bitam
ÉQUATORIAL
DE
TRANSITION
20°
15°
10°
5°
0°
-5°
-15°
-10°
-5°
0°
5°
10°
15°
20°
25°


Rainfall Index for Subsaharan West Africa(1941-98)
Average Normalized Departure
2
1
0
-1
-2
1941
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995

Shift of isohyets after 1970

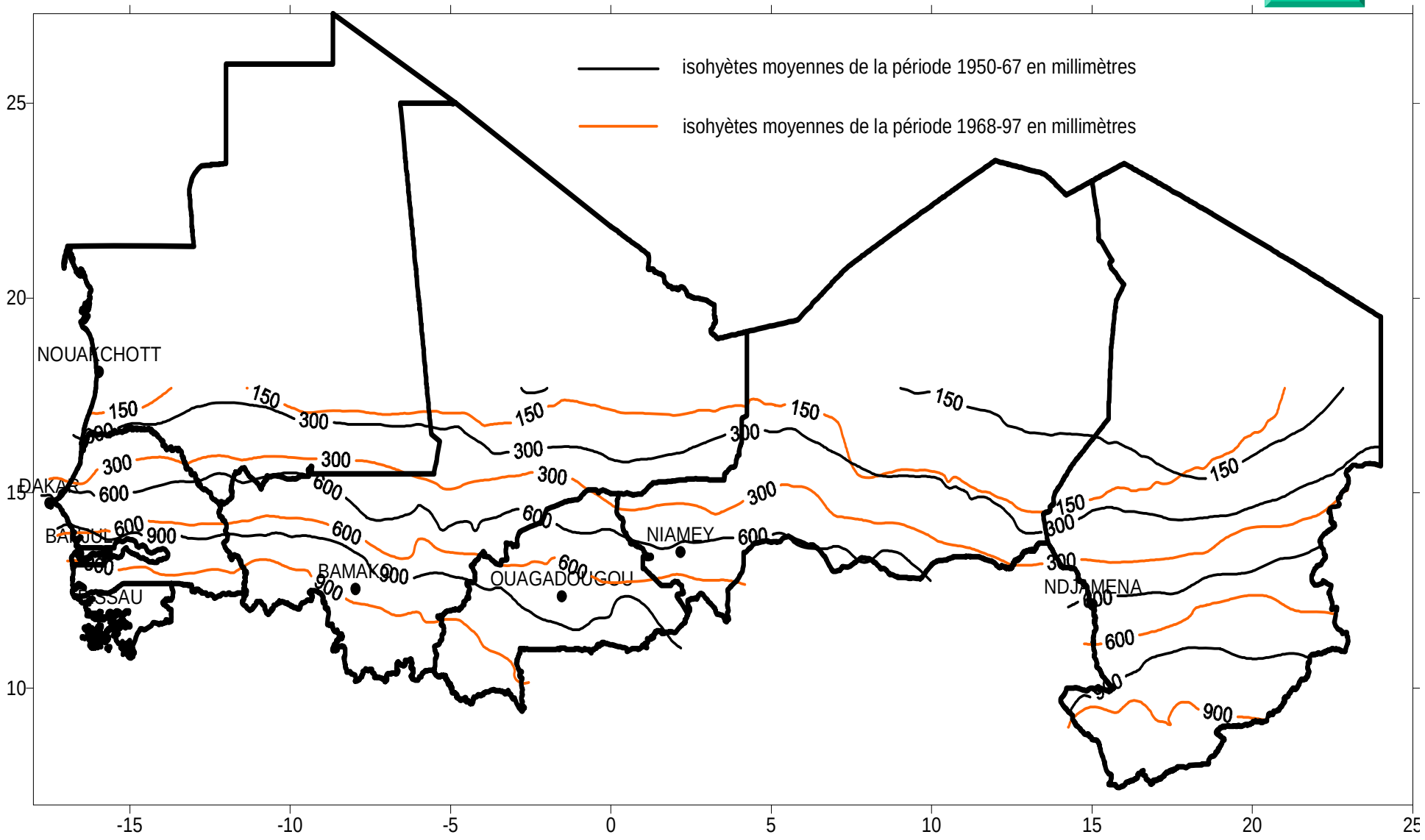
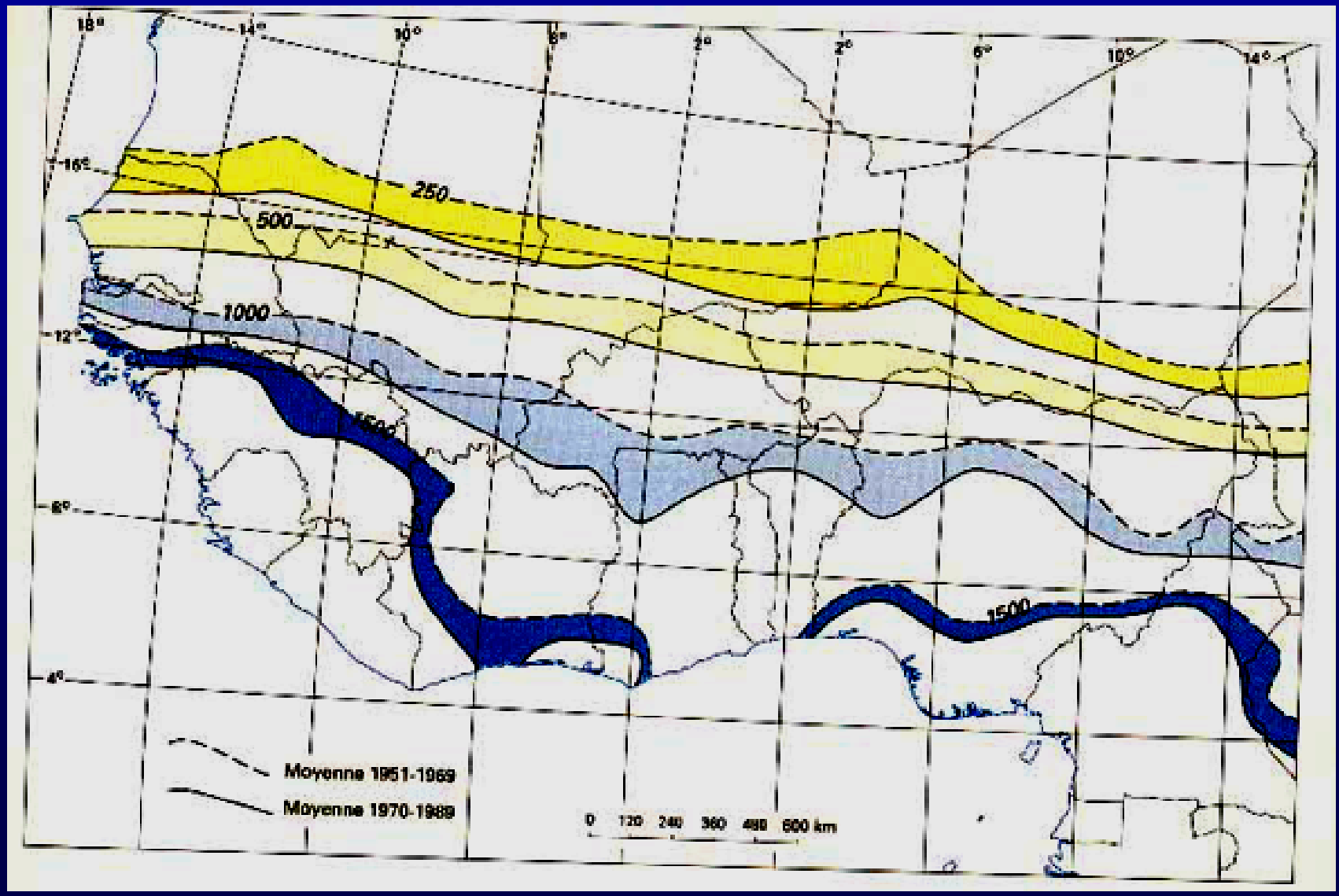
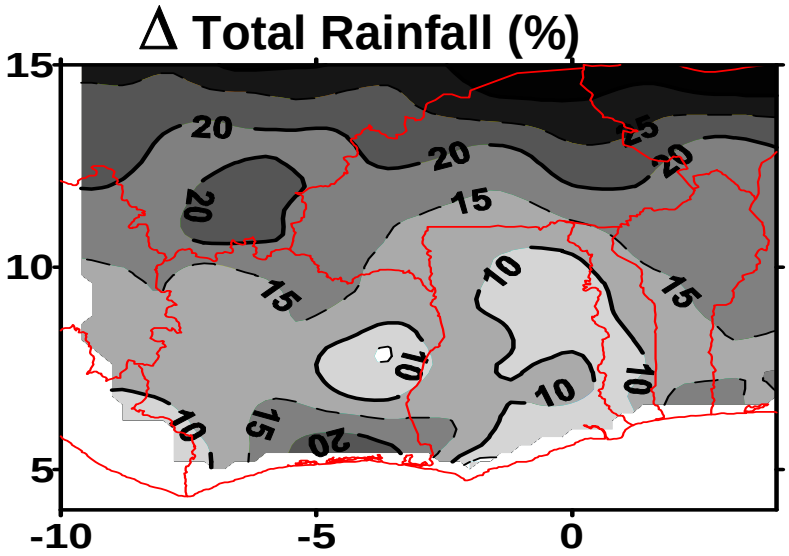
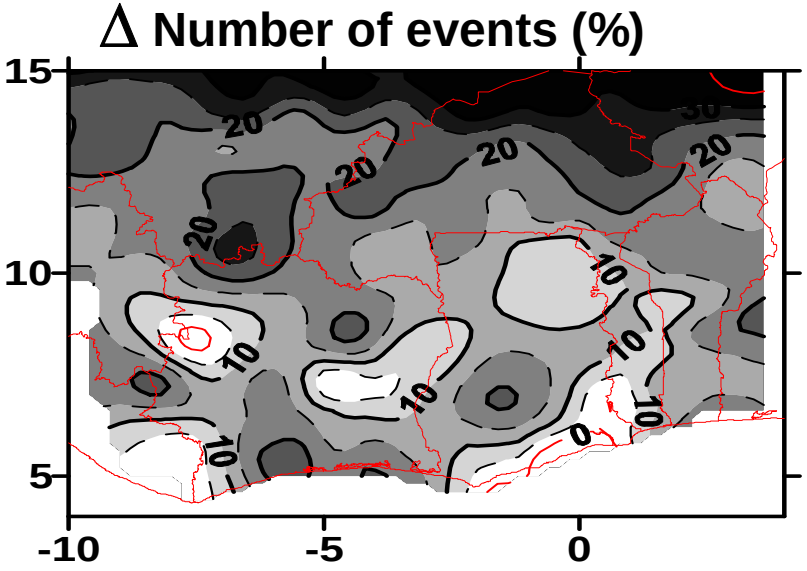
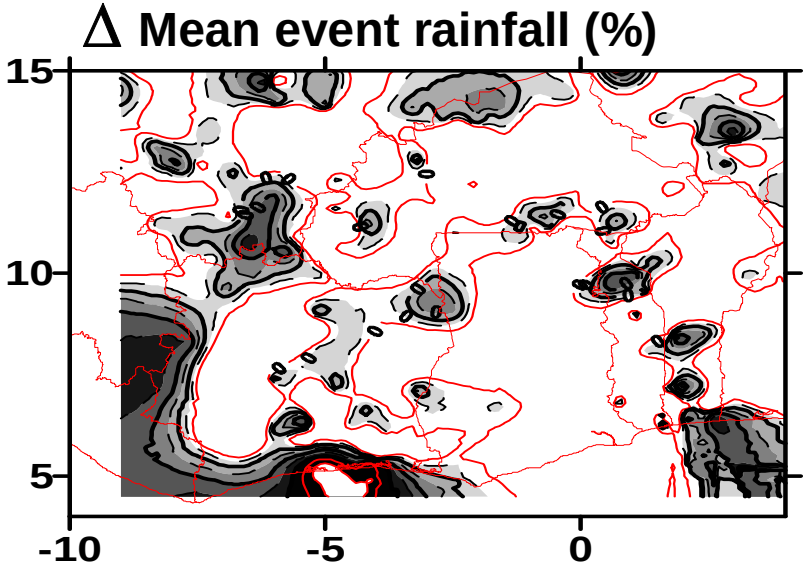


Fig: Déplacement des isohyète vers le sud (L'Hôte, Mahé, 1996)



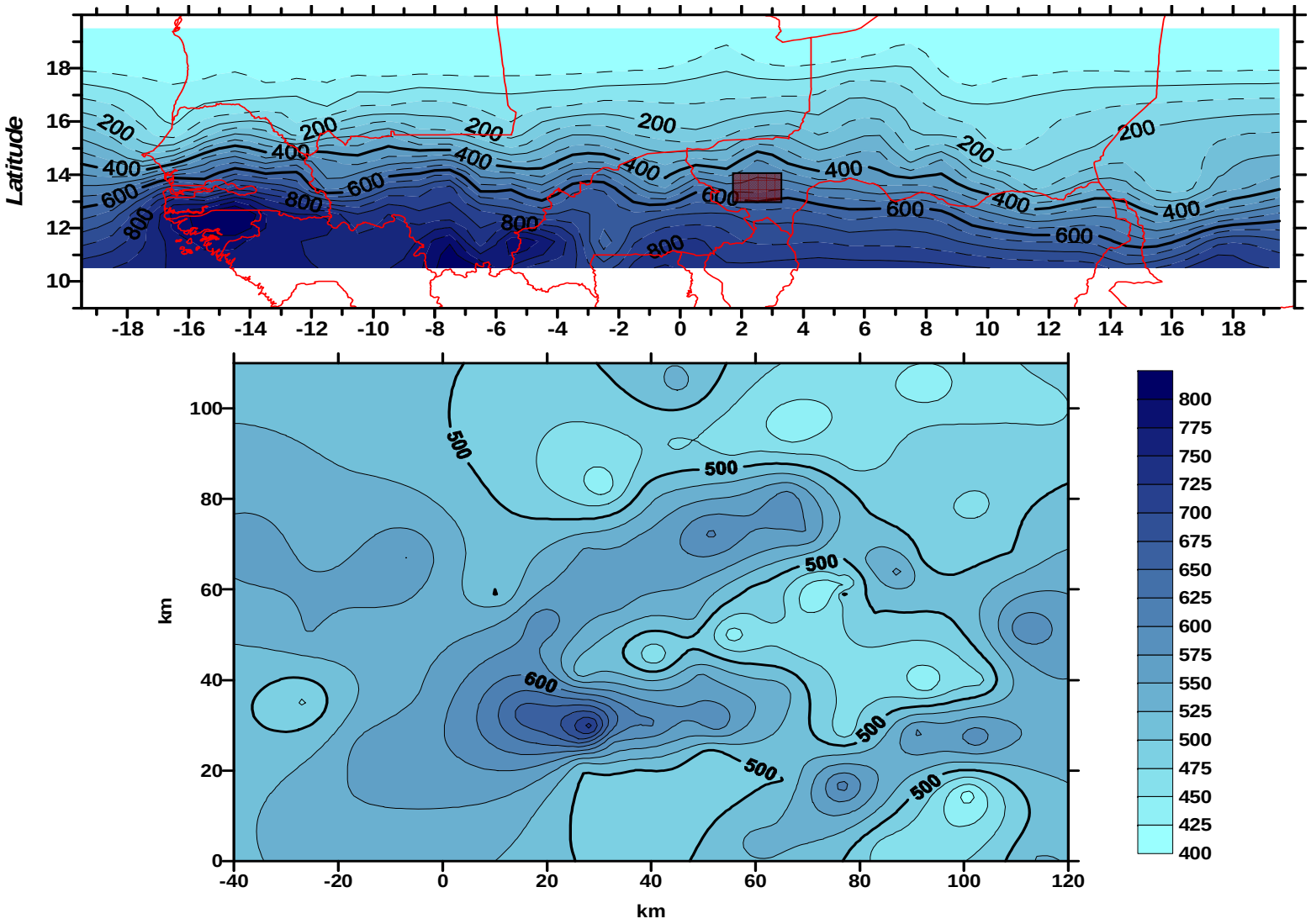

Δ Total Rainfall (%)
15
10
5
-10
-5
0
20
15
10


Δ Number of events (%)
15
10
5
-10
-5
0
20
10

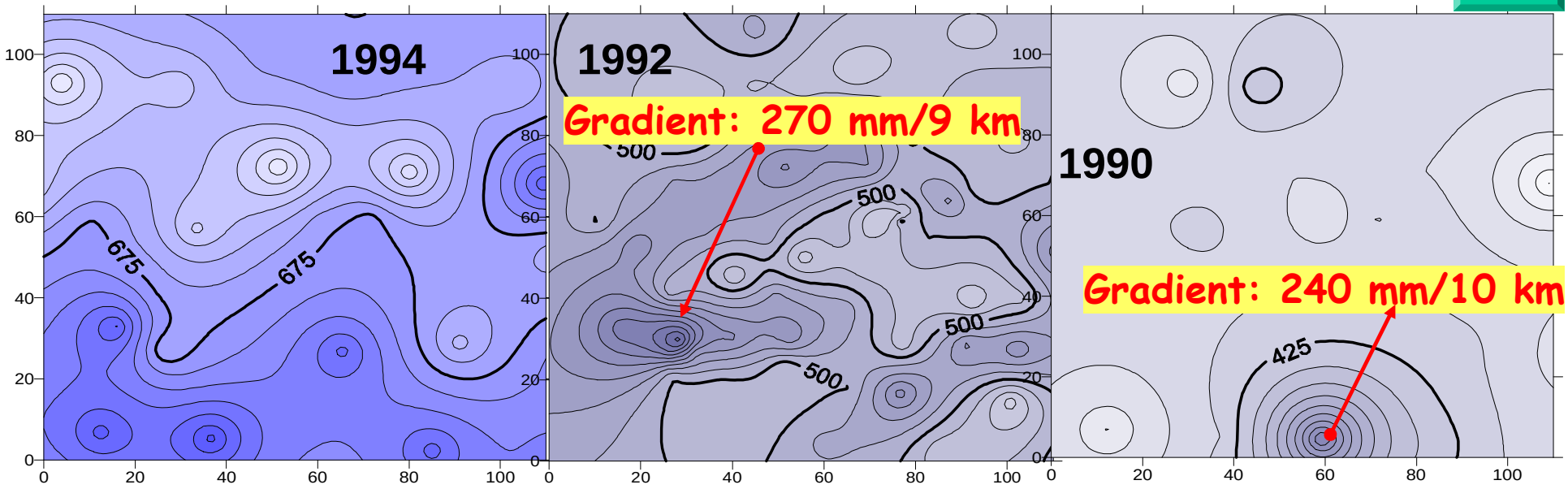

Δ Mean event rainfall (%)
15
10
5
-10
-5
0

The scales of rainfall variability

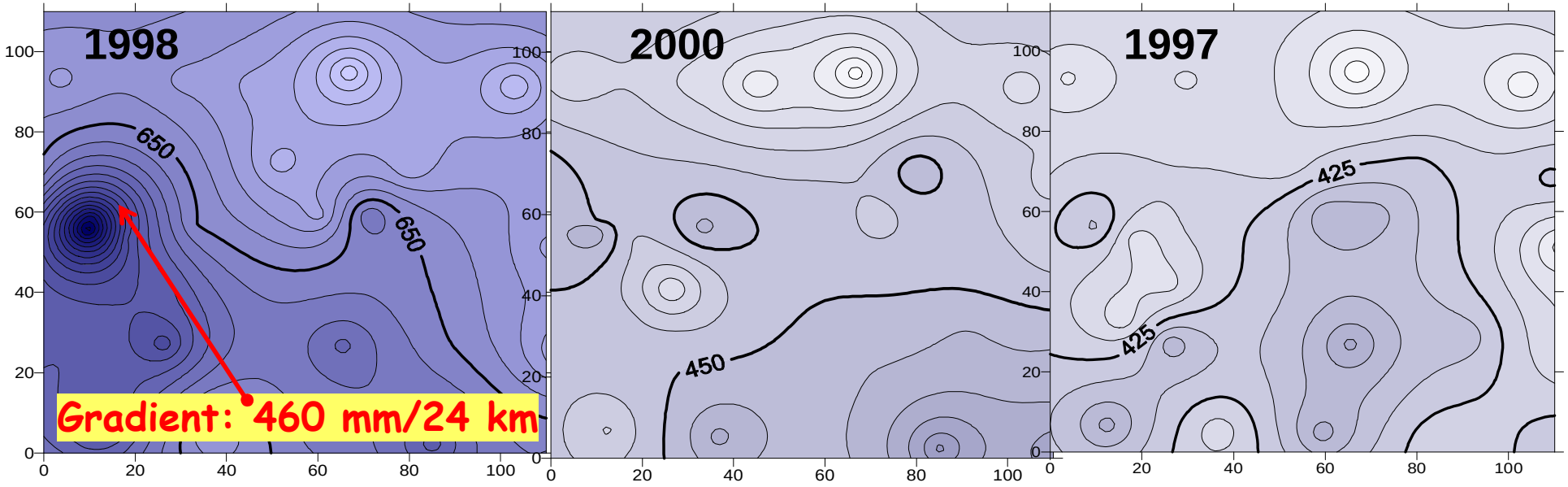
1992



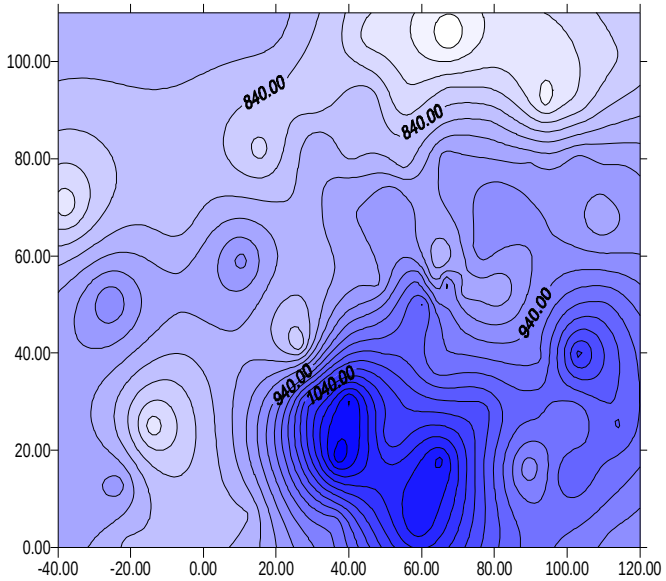
Mesoscale view of Wet vs Dry years



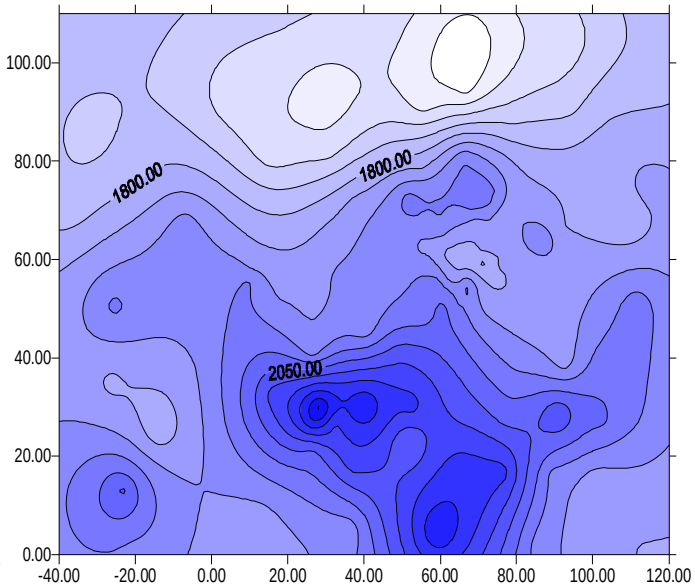
Wet Years | Moderatly dry | Dry Years



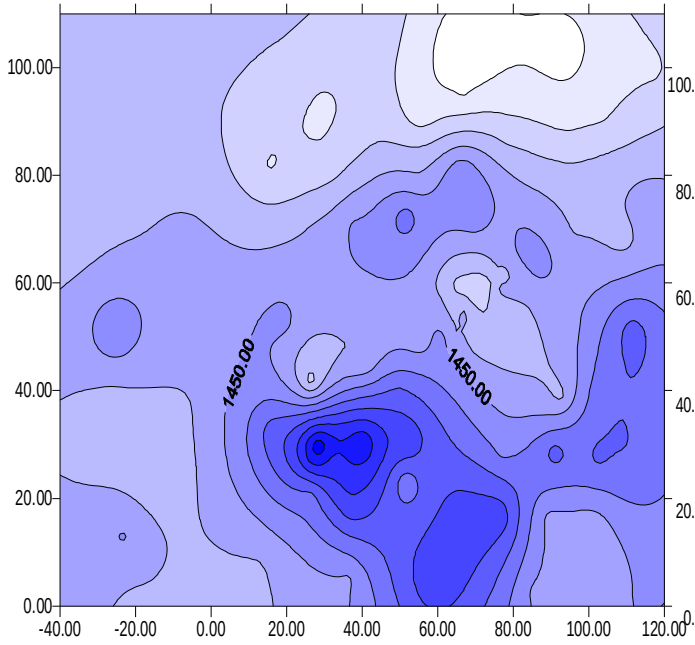
1990



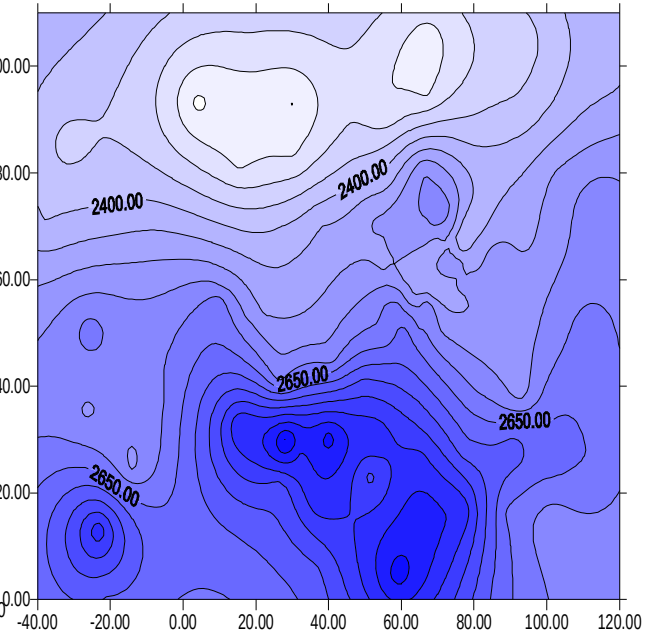
1990-1993

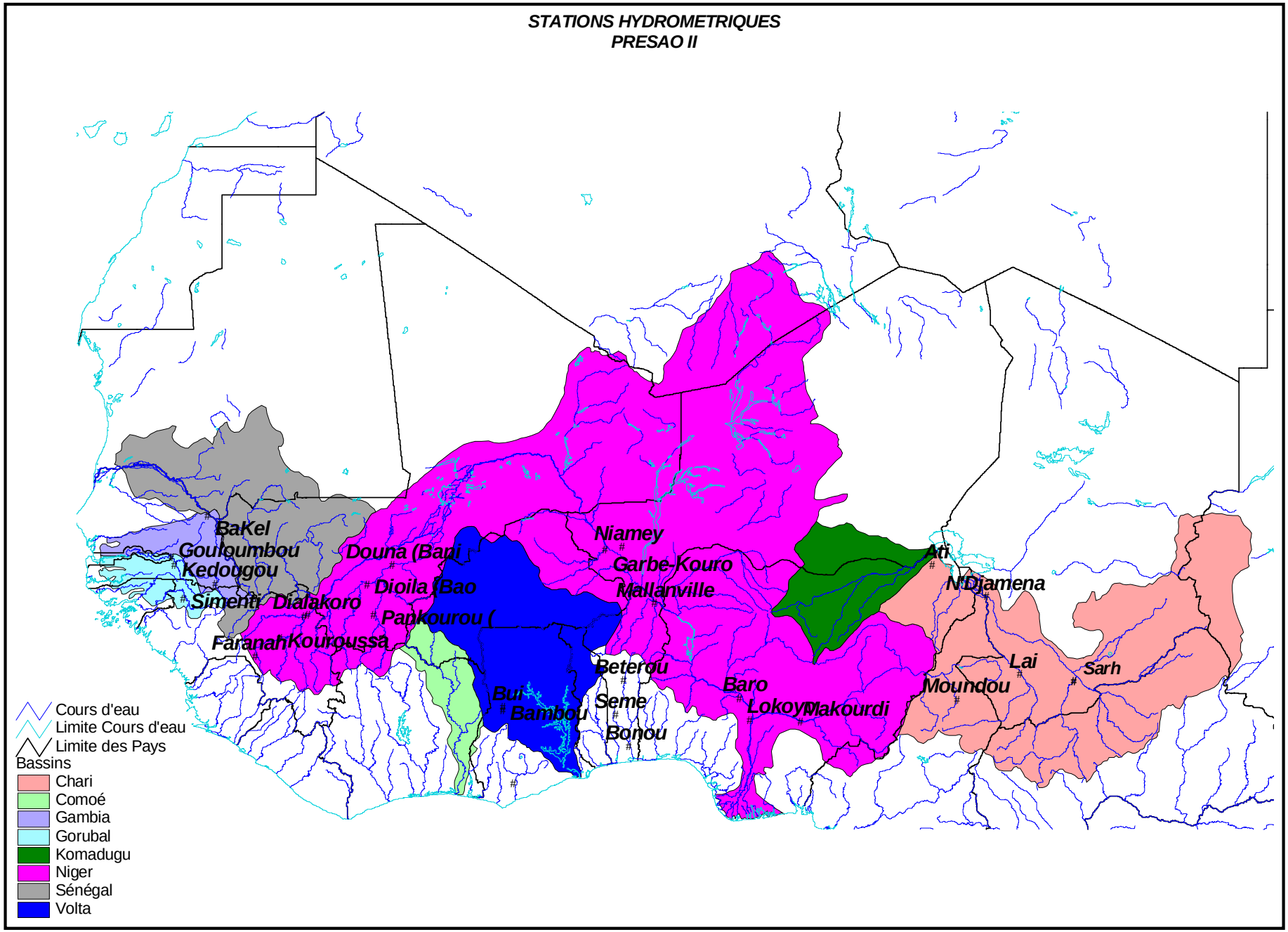


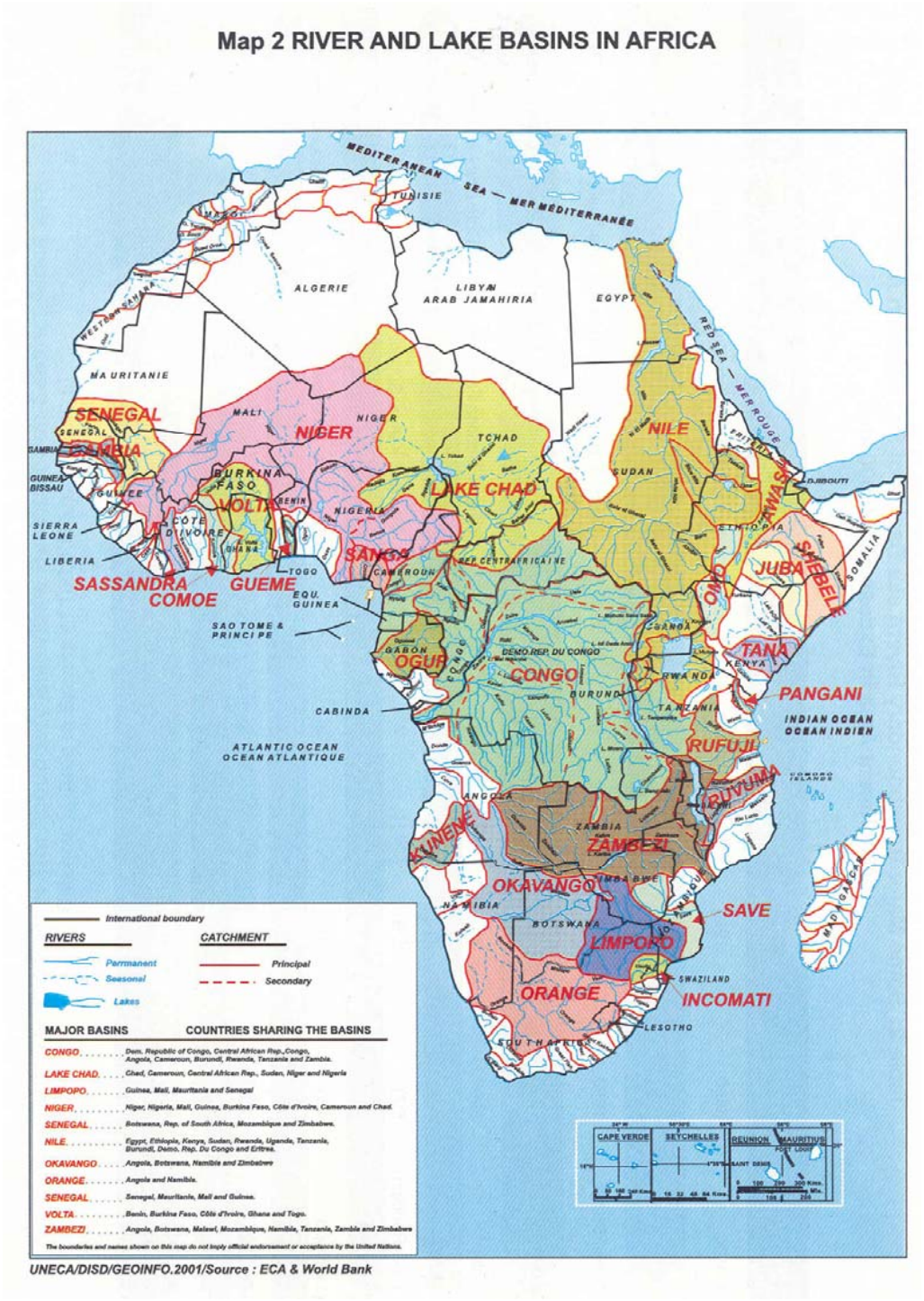
1990-1991



1990-1994




STATIONS HYDROMETRIQUES
PRESAO II
BaKel
Goulgumbou
Kedougou
Simenti
Dialakoro
Faranah
Kouroussa
Douna (Bani
Dioila (Bao
Pankourou (
Niamey
Garbe-Kouro
Mallanville
Beterou
Bui
Bambou
Seme
Bonou
Baro
Lokoyo
Makourdi
Ati
N'Djamena
Lai
Moundou
Sarh
Cours d'eau
Limite Cours d'eau
Limite des Pays
Bassins
Chari
Comoé
Gambia
Gorubal
Komadugu
Niger
Sénégal
Volta

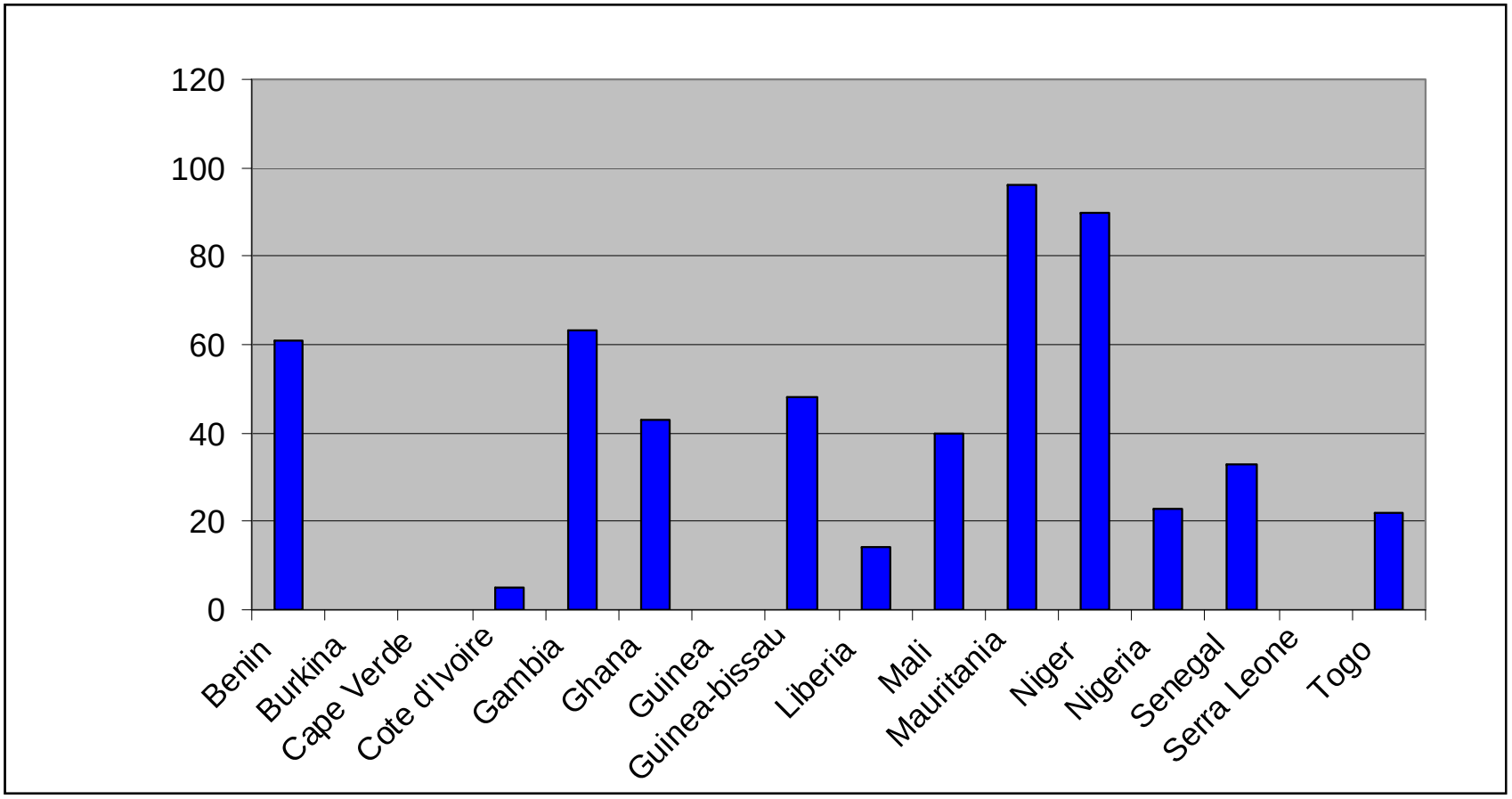


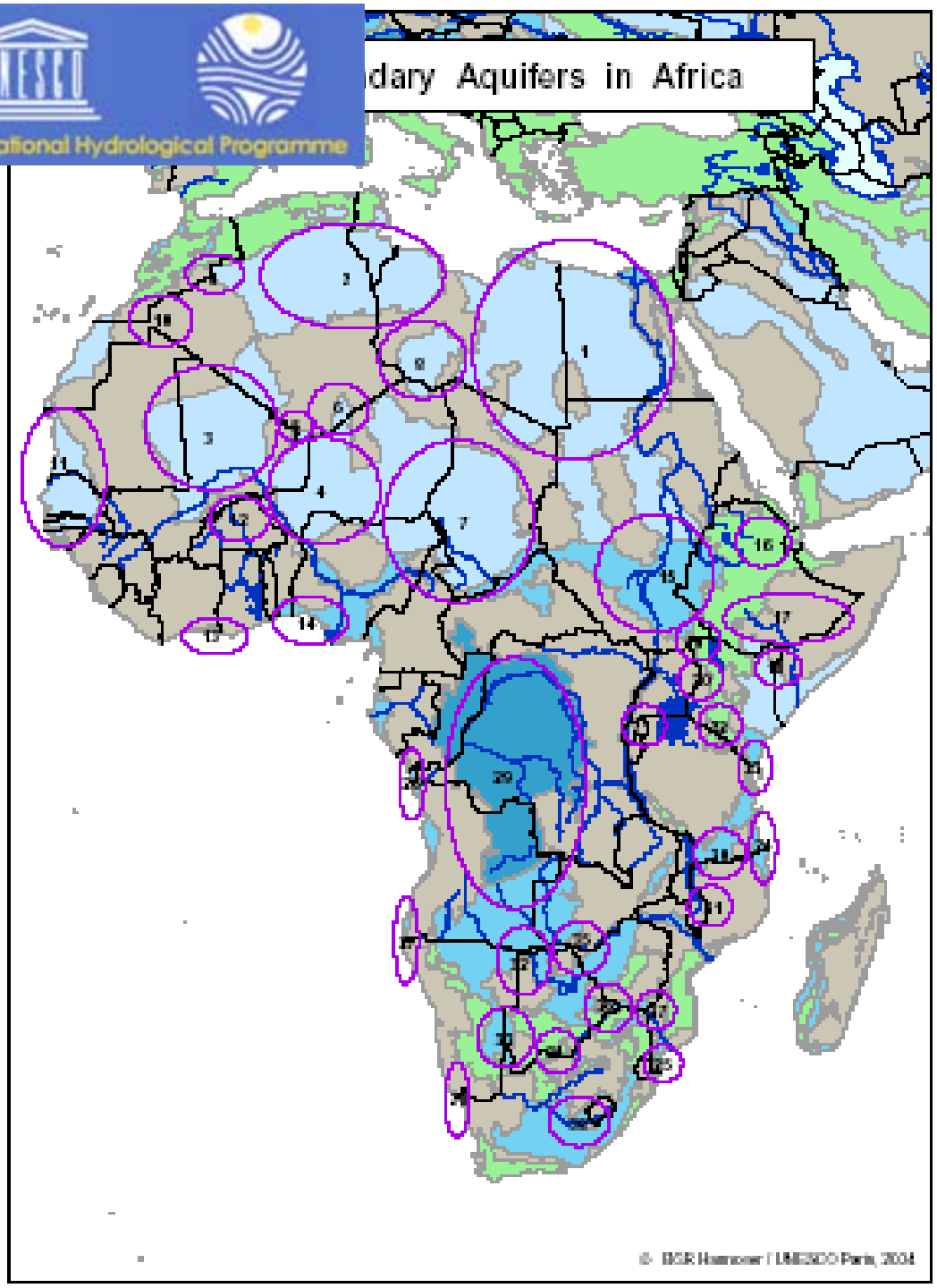
UNECA/DISD/GEOINFO.2001/Source : ECA & World Bank

75% of Surface Water concentrated major basins: congo, Niger, Zambezi, Nile, Chari-logone, Volta, limpopo, Senegal, Orange)

Over 80 transboundary river/lake basins

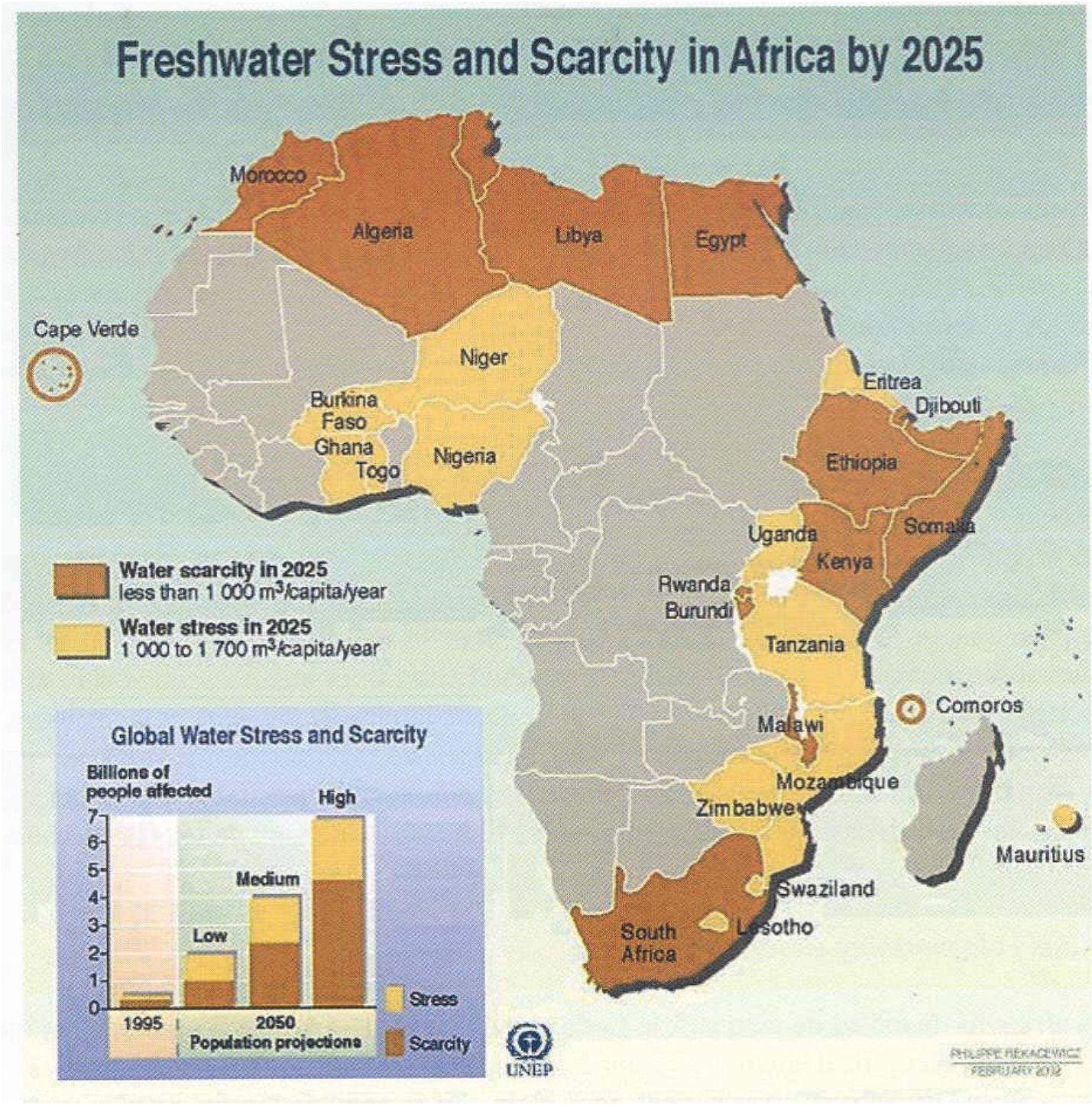
Water Dependance Index, UNWWDR2, AQUASAT, FAO, 2005





Around 41 transboundary aquifers identified so far

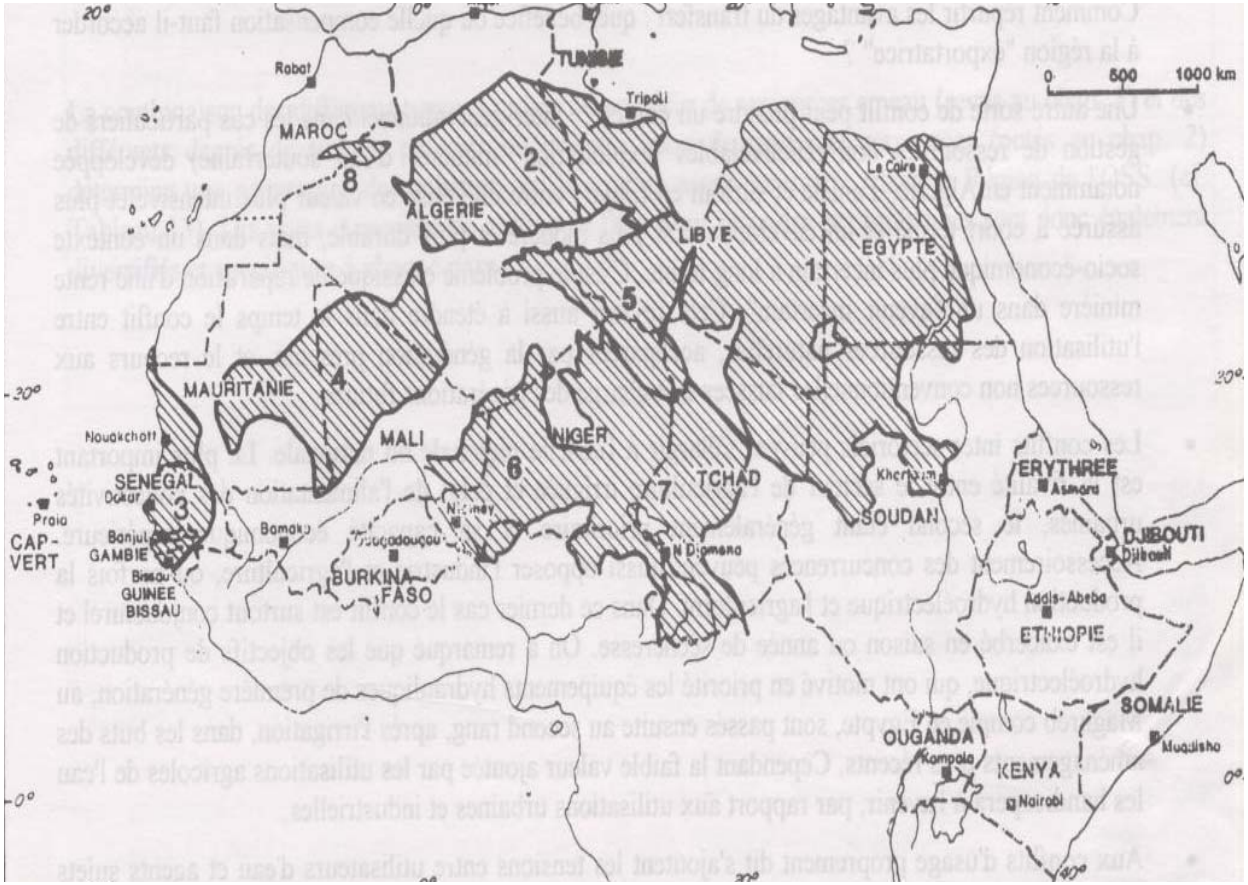
There is a great lack of scientific knowledge on TBA in Africa


Freshwater Stress and Scarcity in Africa by 2025
Morocco
Algeria
Libya
Egypt
Cape Verde
Niger
Burkina Faso
Ghana
Togo
Nigeria
Eritrea
Djibouti
Ethiopia
Somalia
Uganda
Kenya
Rwanda
Burundi
Tanzania
Comoros
Malawi
Mozambique
Zimbabwe
Mauritius
Swaziland
Lesotho
South Africa
Water scarcity in 2025
less than 1 000 m3/capita/year
Water stress in 2025
1 000 to 1 700 m3/capita/year
Global Water Stress and Scarcity
Billions of people affected
High
Medium
Low
1995
2050
Population projections
Stress
Scarcity
UNEP
PHILIPPE REKACEWICZ
FEBRUARY 2002

Eaux souterraines

Partagées entre plusieurs pays;

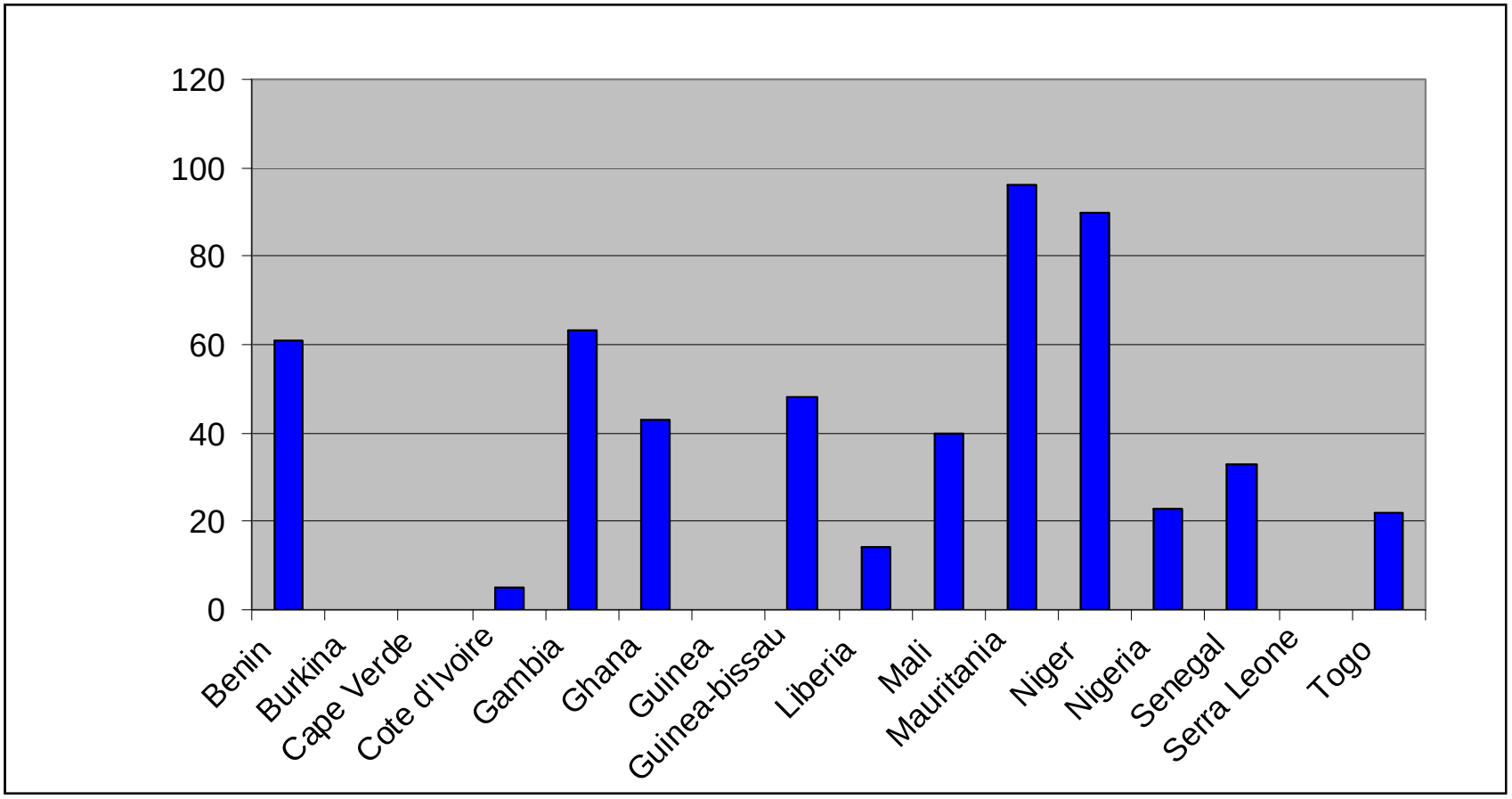
- De profondeurs variables suivant les formations géologiques
- Très mal connues en quantité et qualité, même si des importantes quantités d'eau sont disponibles (très peu de mesures piézométriques)
- Principales sources d'eau potable pour l'alimentation des populations
- Problèmes de qualité (intrusion saline surtout pour les nappes côtières)



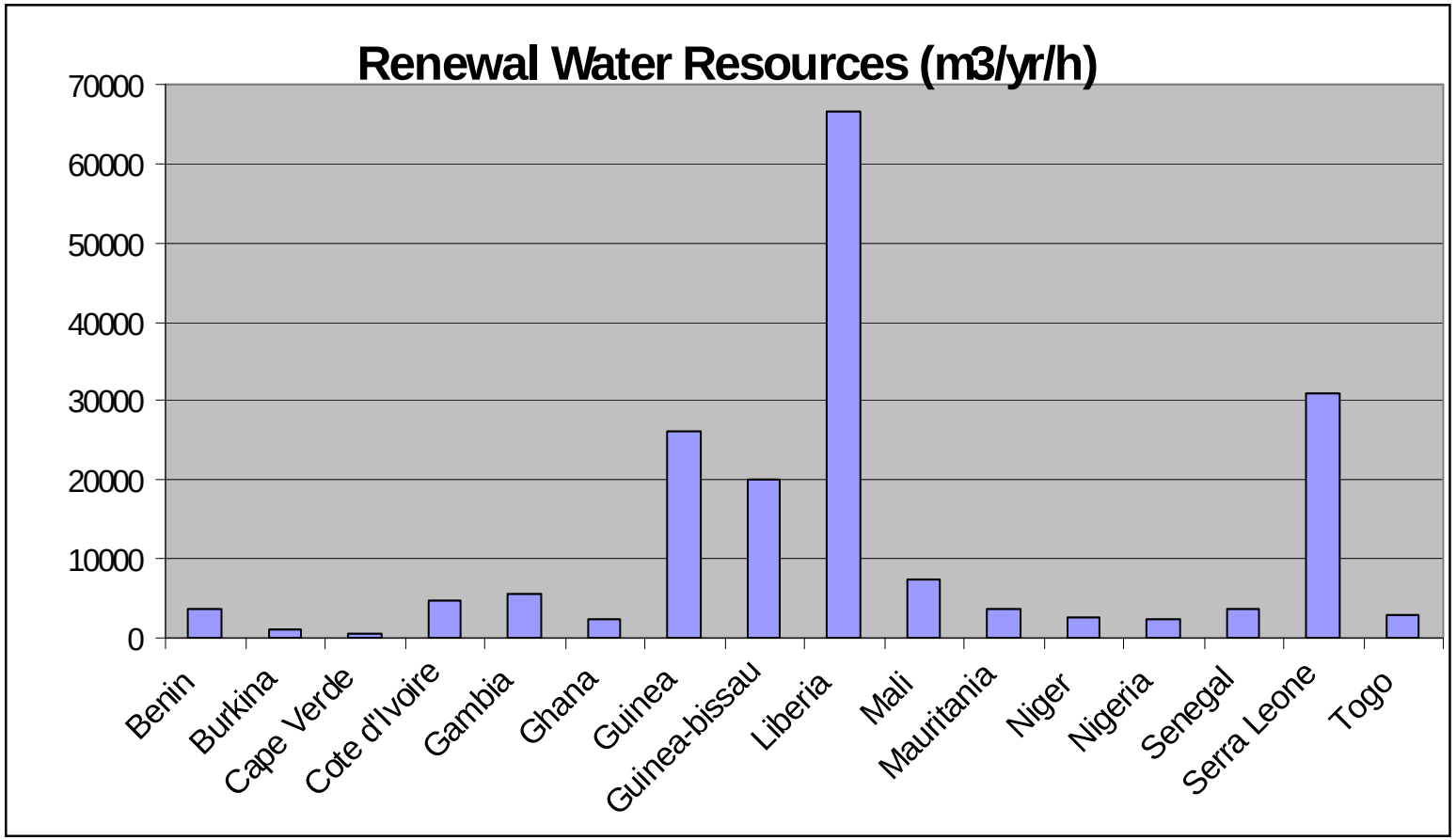
1. Bassin de Nubie – 2. Sahara Septentrional – 3. Bassin Sénégal-Mauritanien – 4. Bassin de Taoudéni – 5. Bassin de Mourzouk-Djado – 6. Bassin Irhazer-Iullemeden – 7. Bassin du Tchad – 8. Bassin d'Errachidia

Source : Unesco, 1995

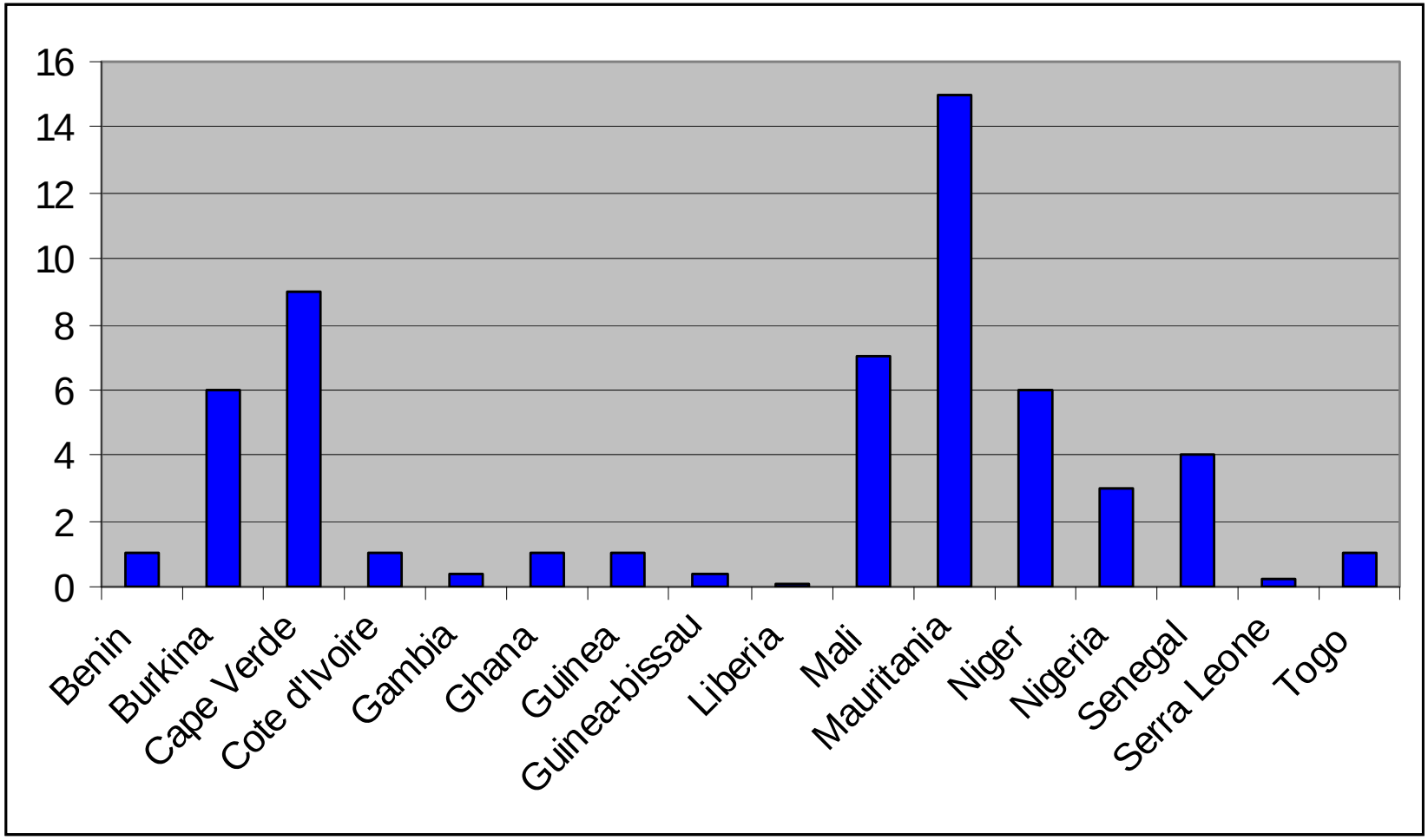
Indices de dépendance, AQUASAT, FAO, 2005



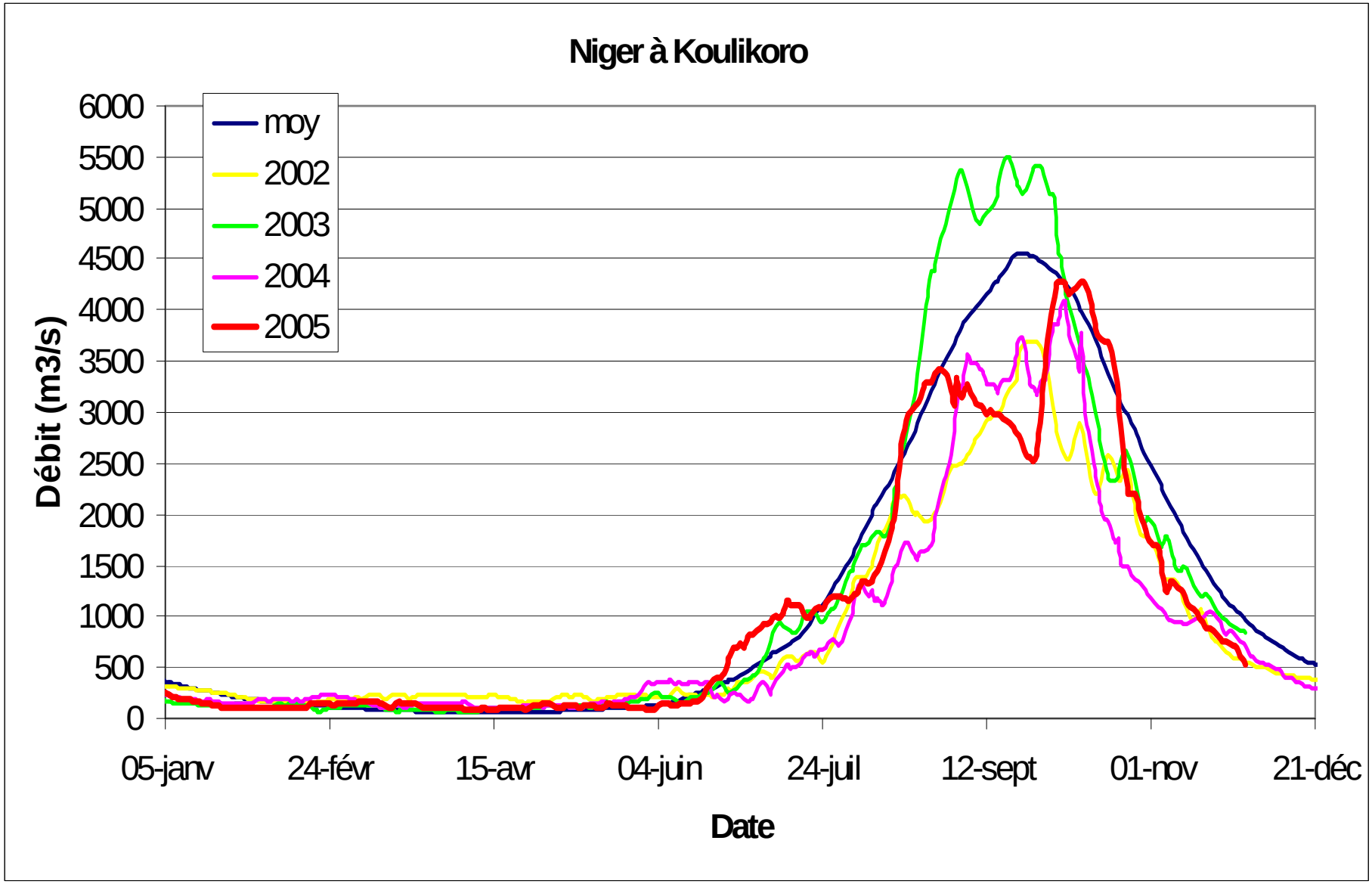
Water Resources 2005 (FAO, AQUASAT, 2005)

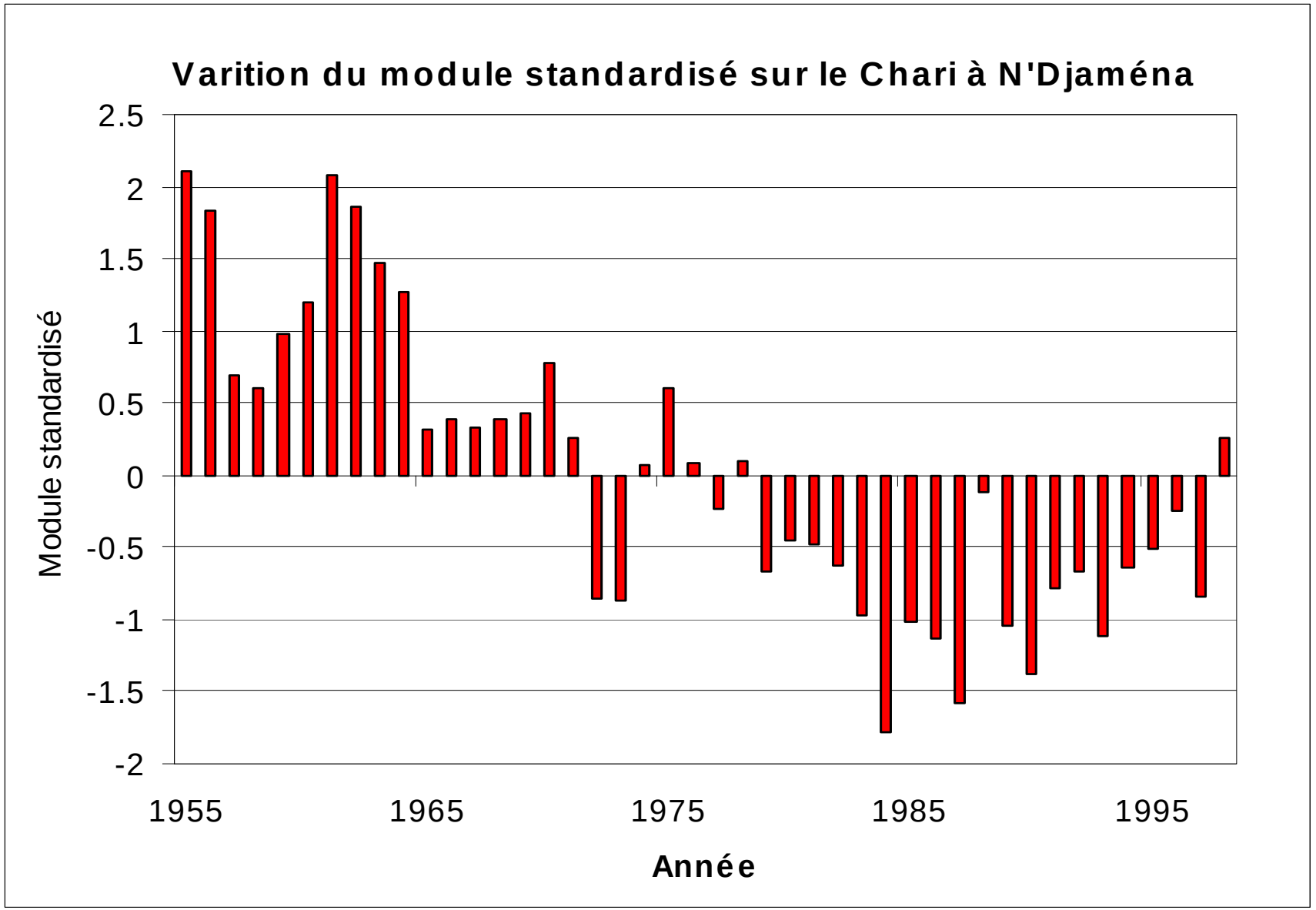


Water mobilisation index (FAO, AQUASAT, 2005)

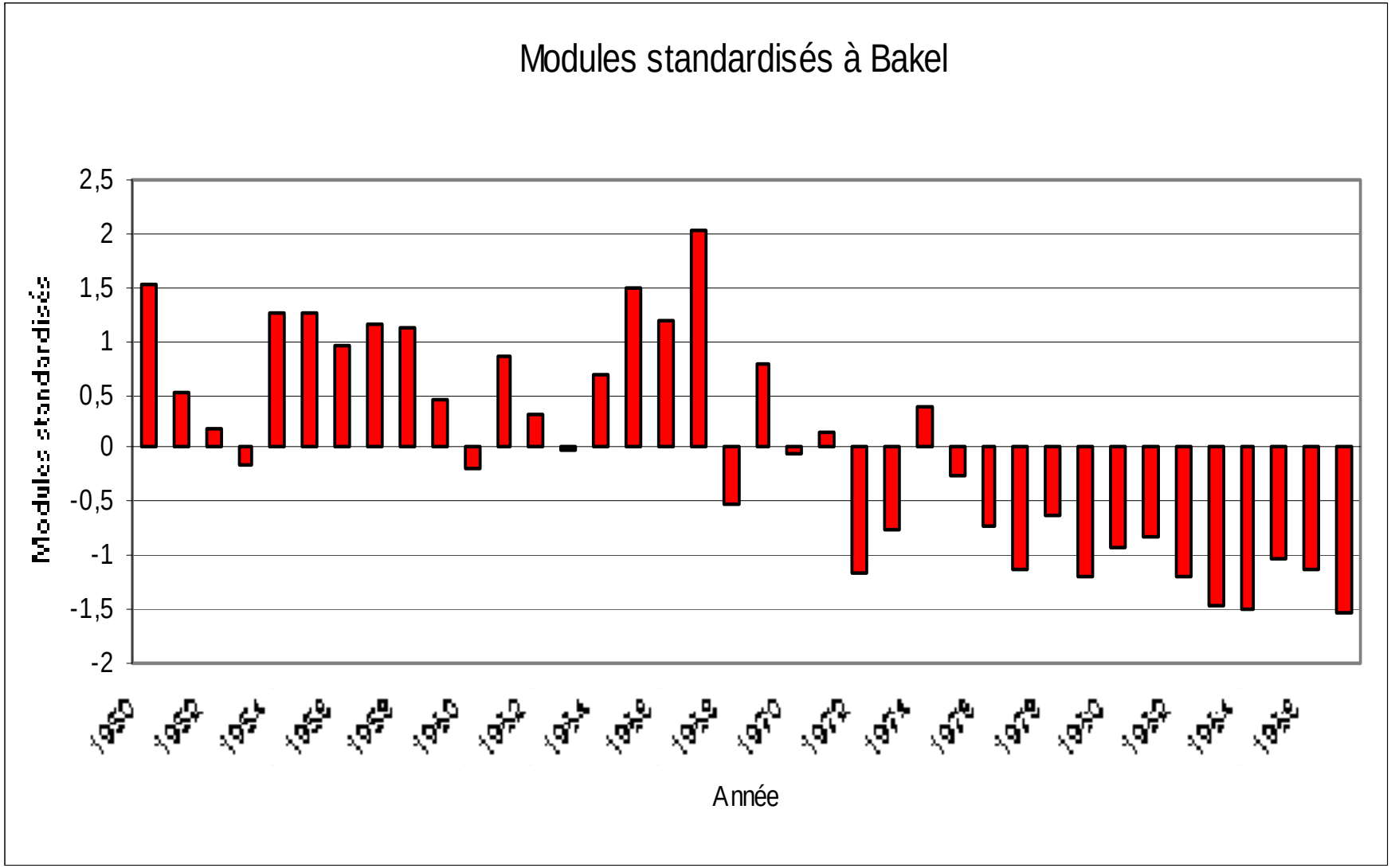


UPPER NIGER BASIN

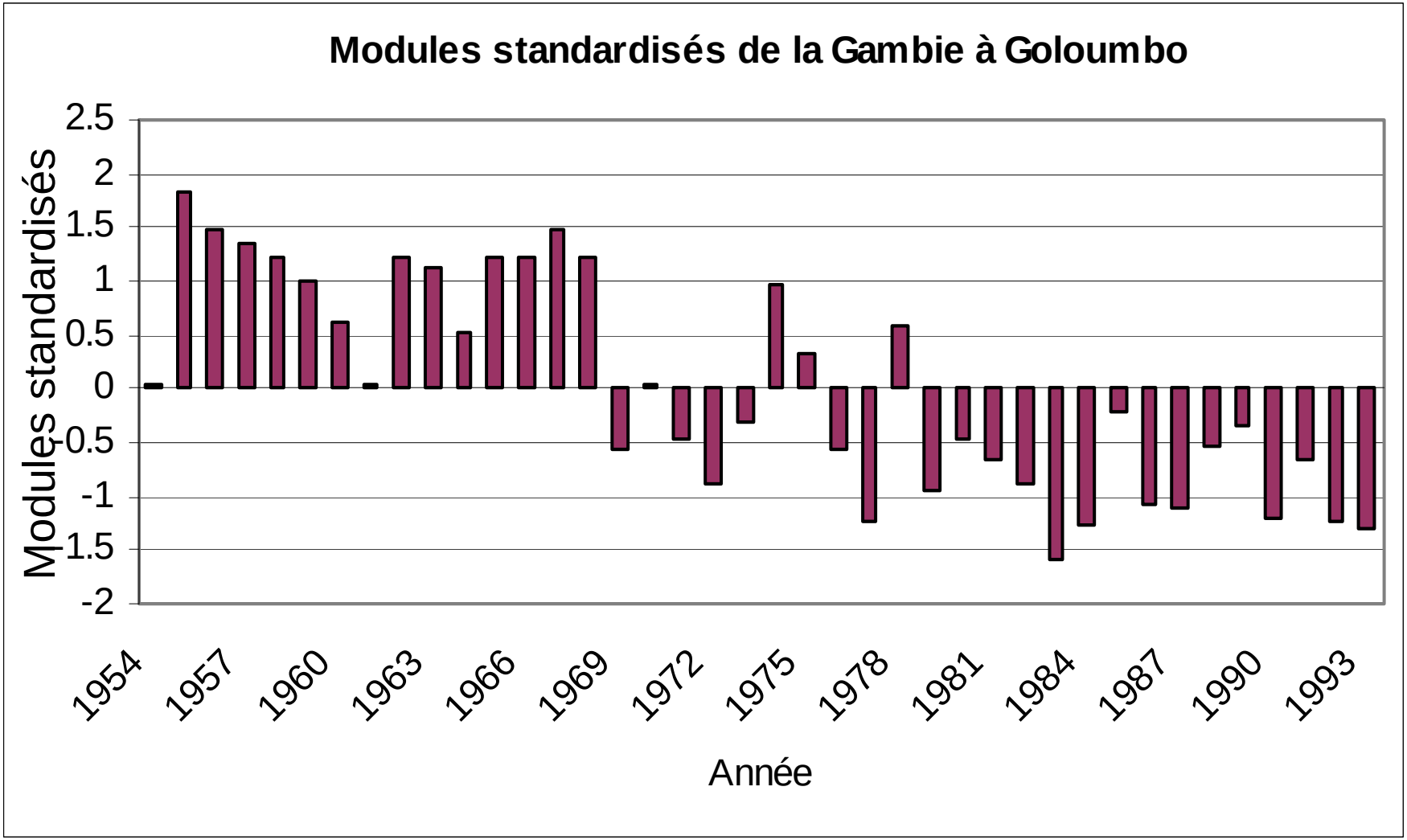



Varition du module standardisé sur le Chari à N'Djaména
Module standardisé
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1955
1965
1975
1985
1995
Année

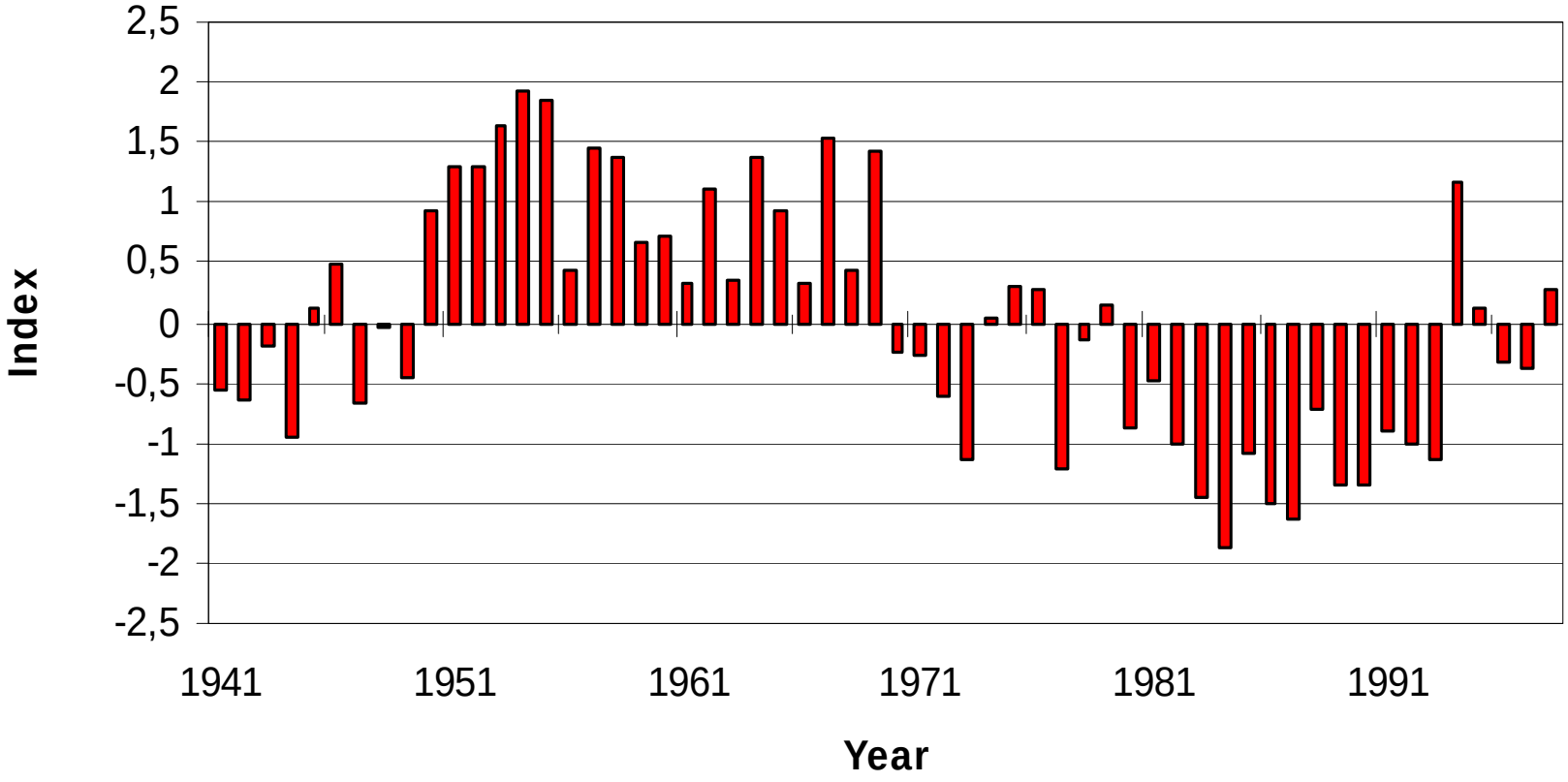
Mean annual discharge index at Bakel before Manantali Dam



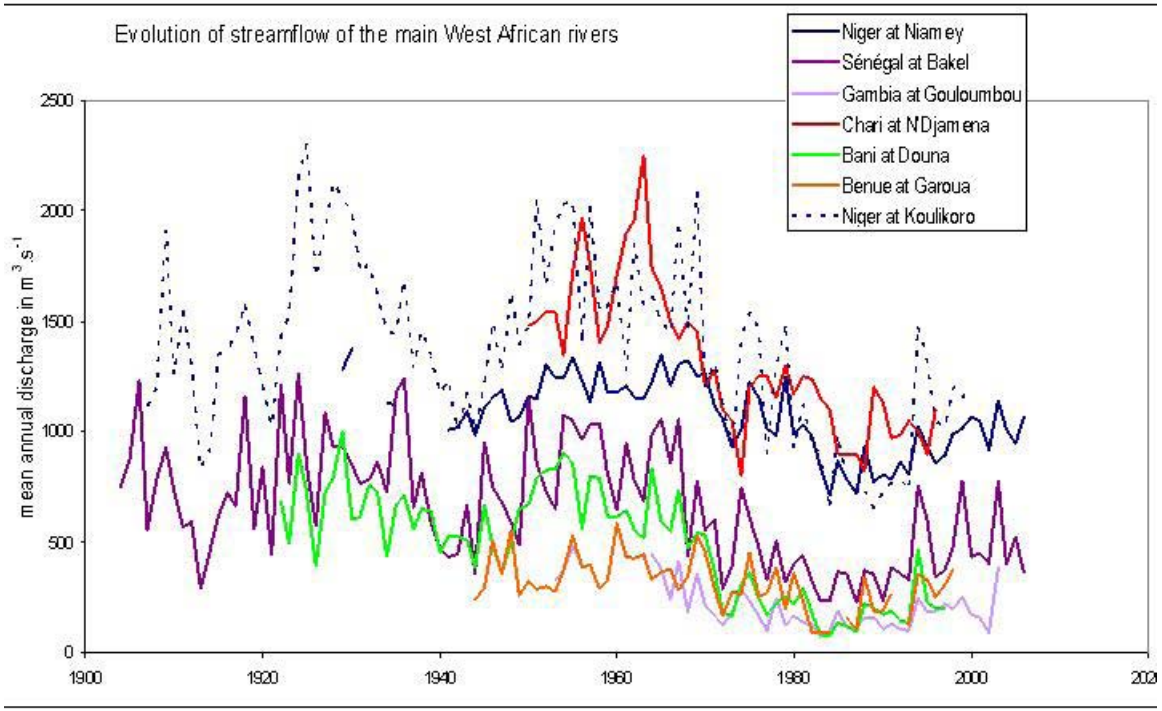
Mean annual discharge indexes at Golombo on Gambia river



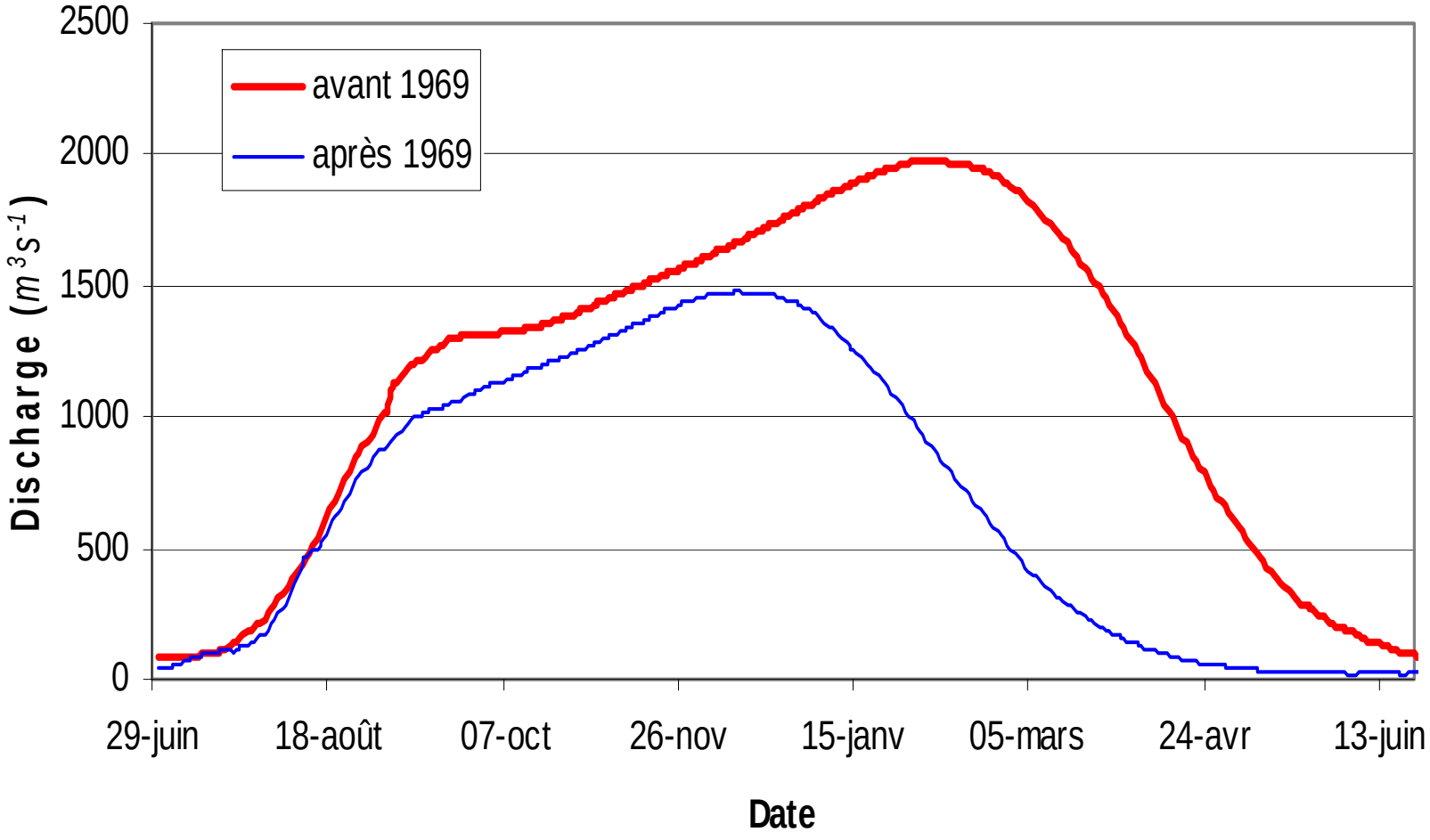
Standardarized mean annual discharge at Niamey on Niger River



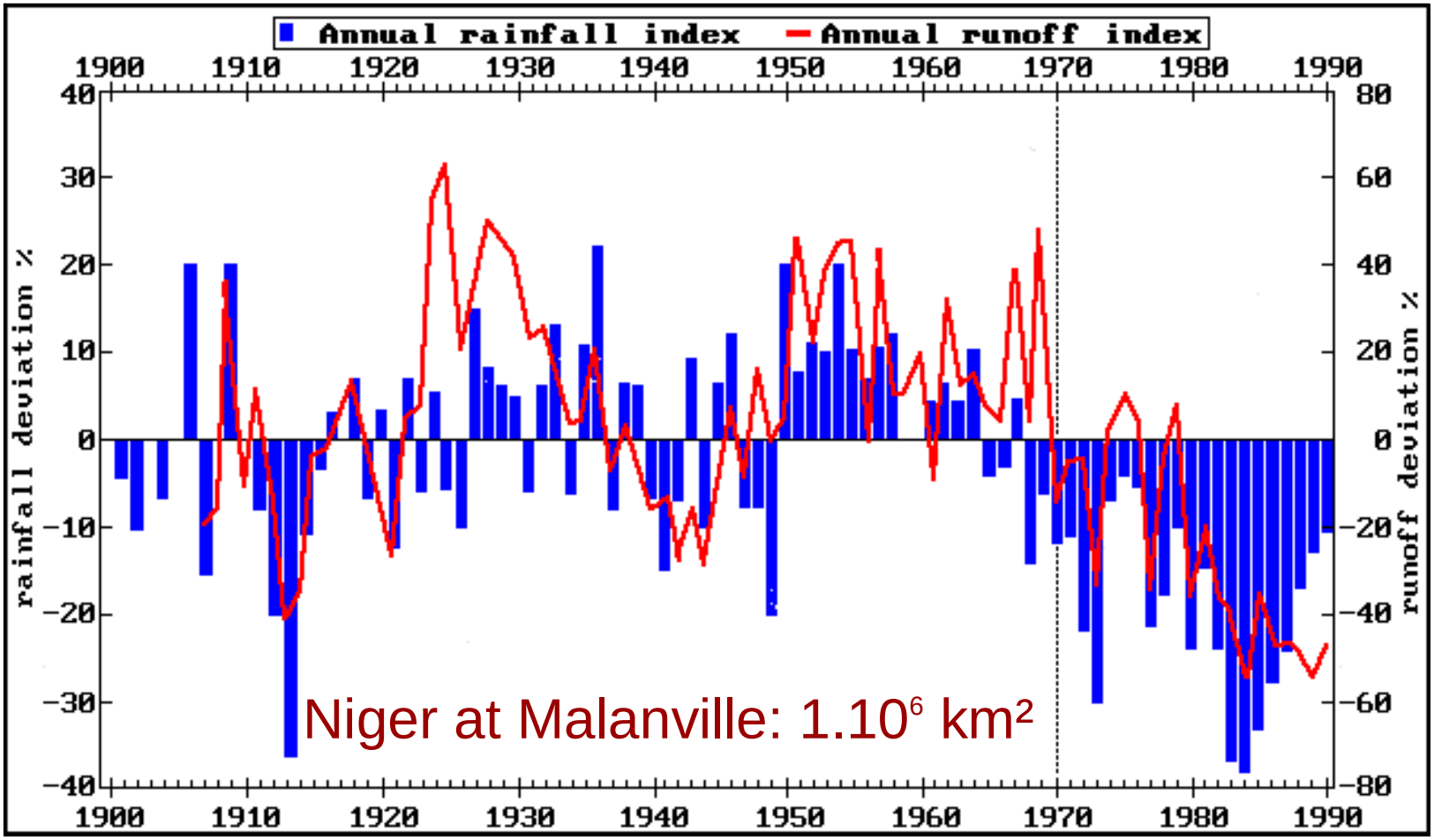
Streamflows of main rivers in WA



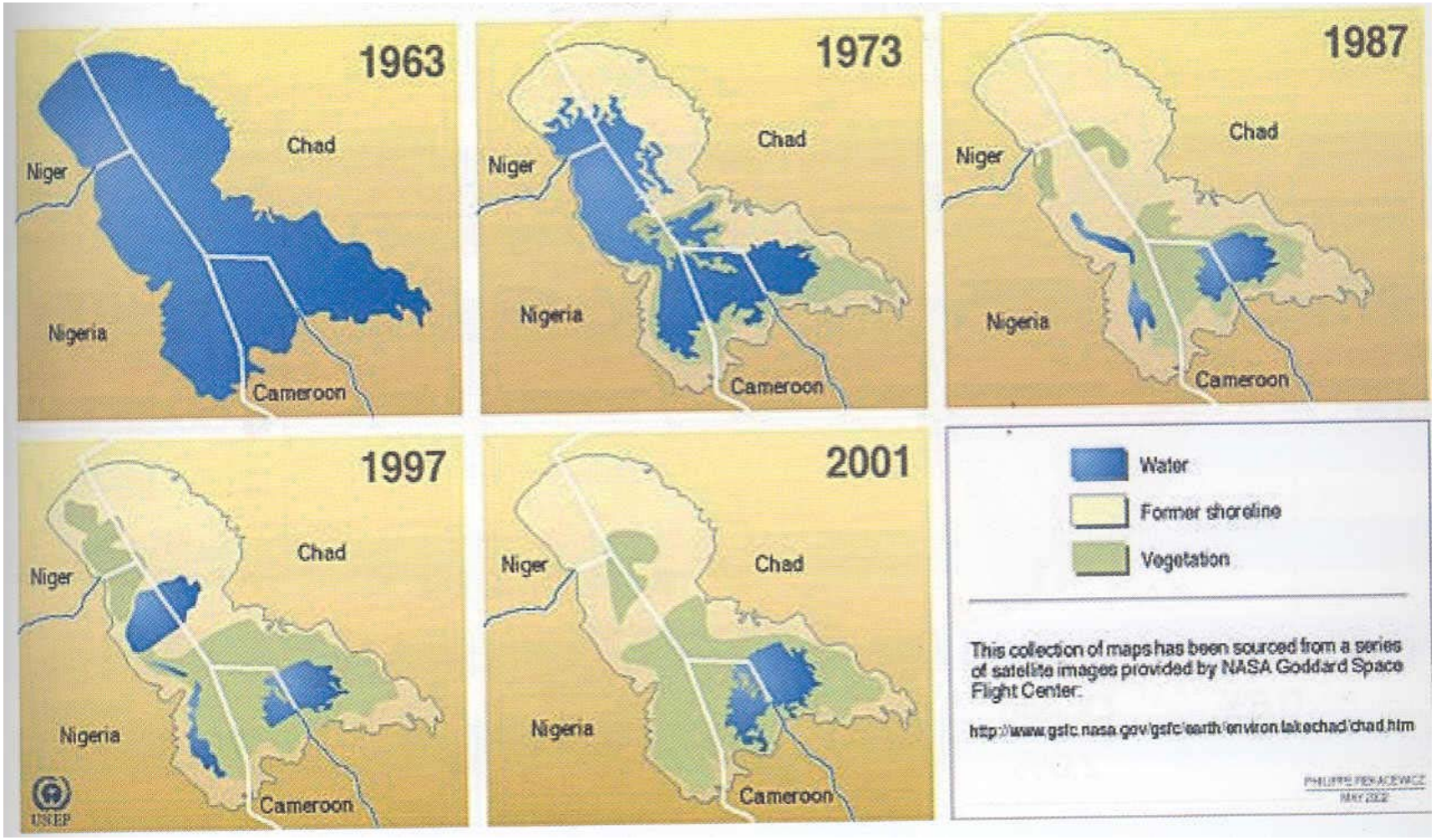
Evolution of mean daily discharge before and after 1969 at Niamey River station



Changes compared



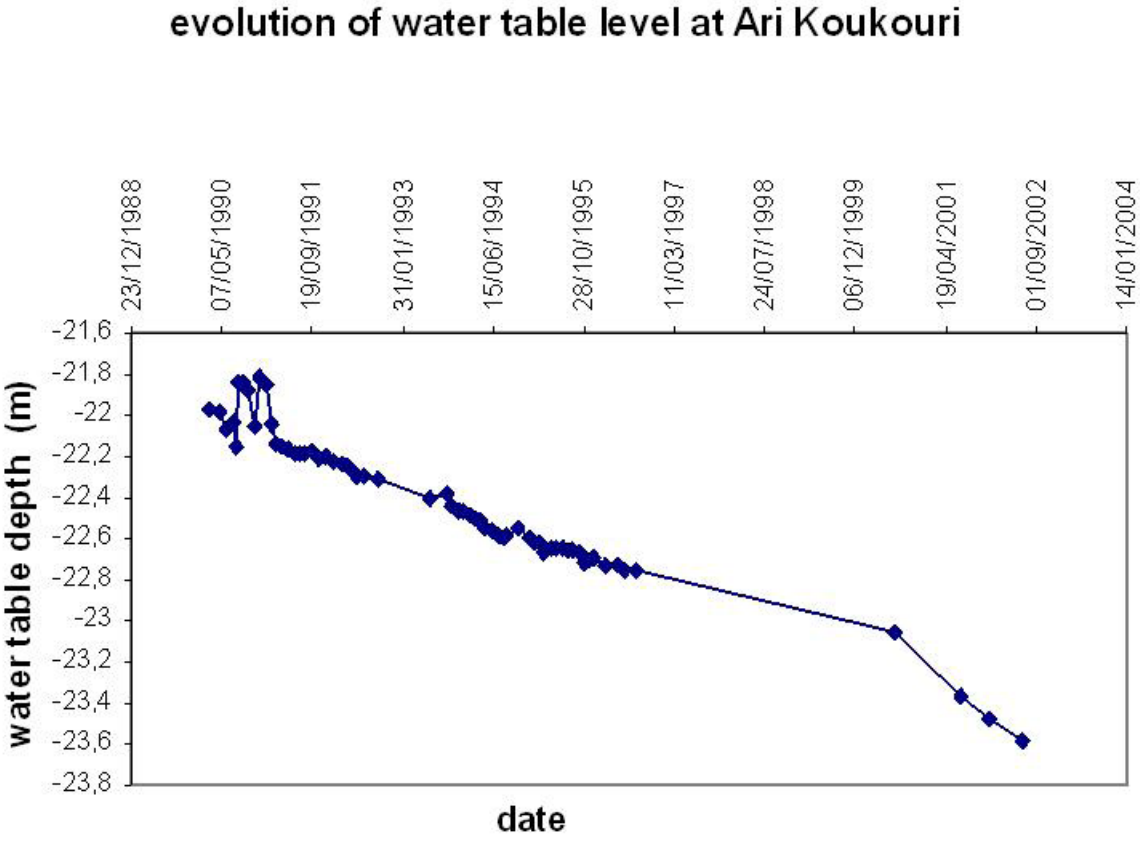
Lake Chad decrease



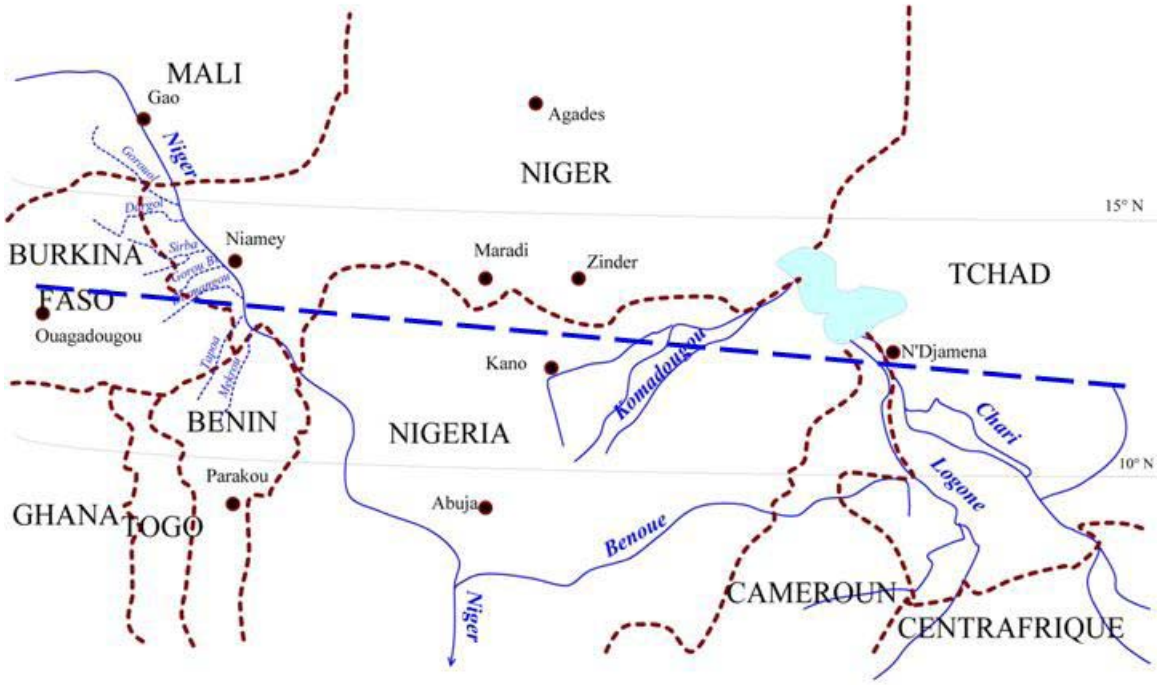
Le Fleuve Niger à NIAMEY : étiage sévère connu en 1985

N.B. Cas aussi du Bani à DOUNA (Mali) respectivement en 1984 et 1987

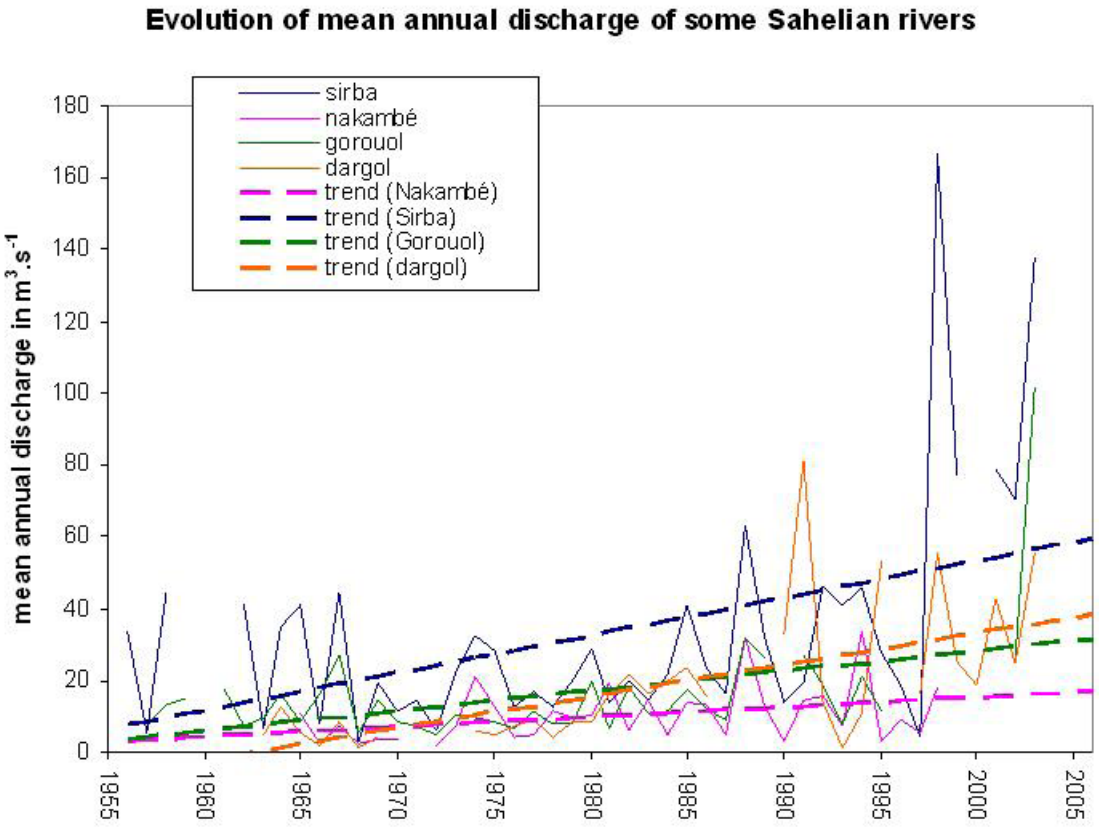
Decrease of aquifer water table



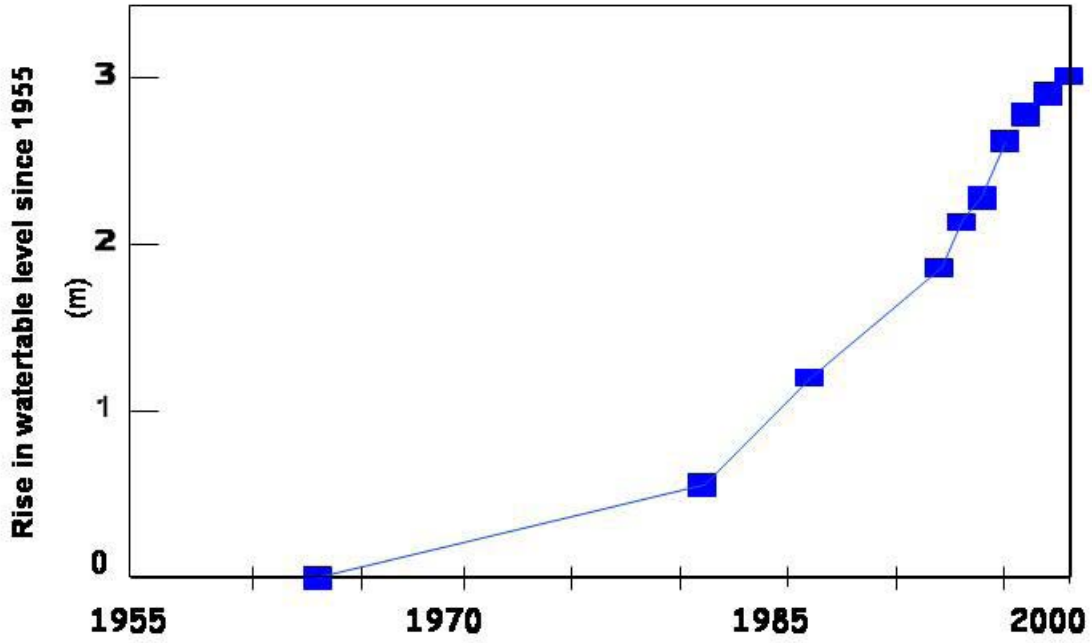
Two Different regimes

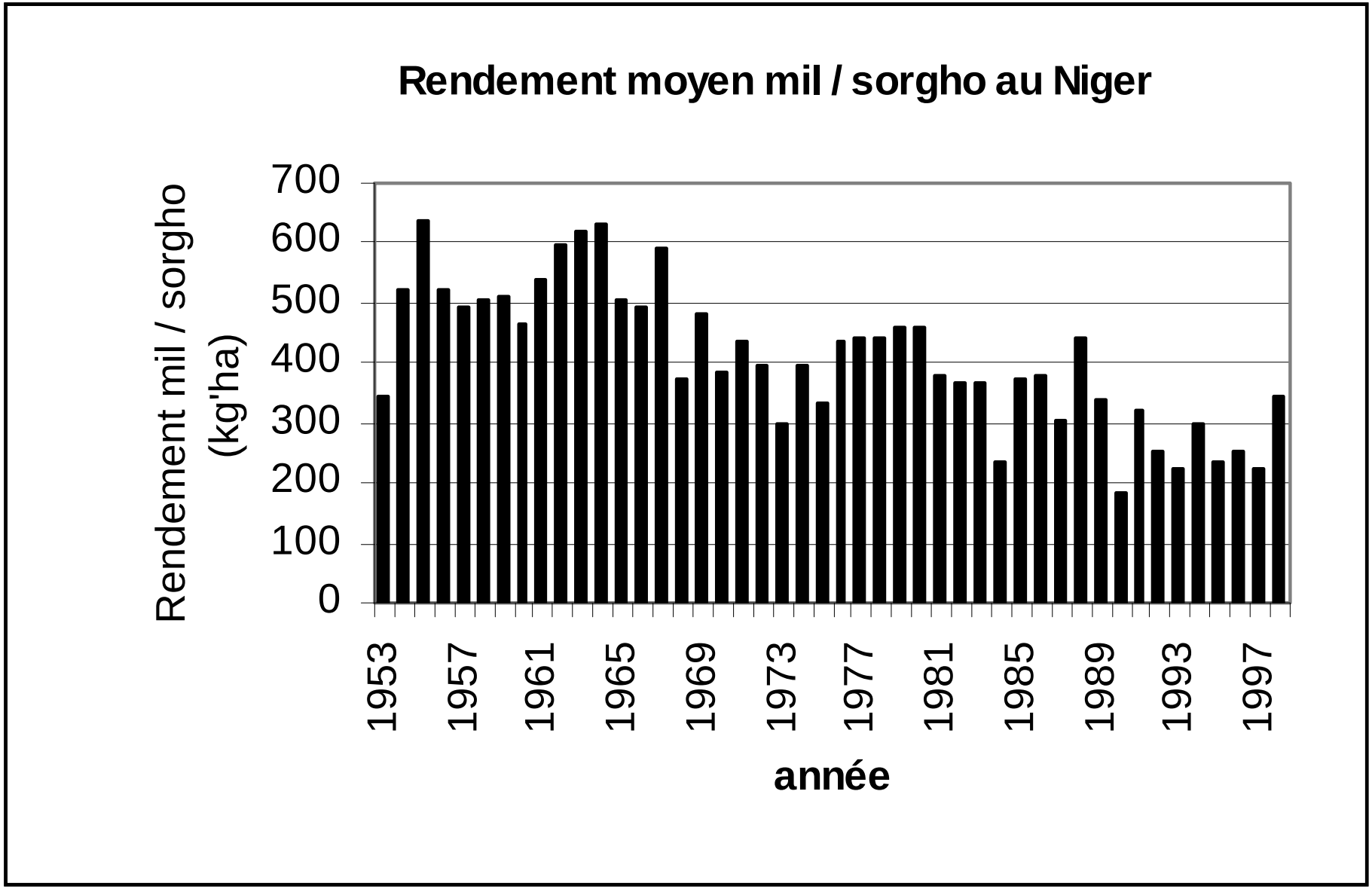


Increase of discharge

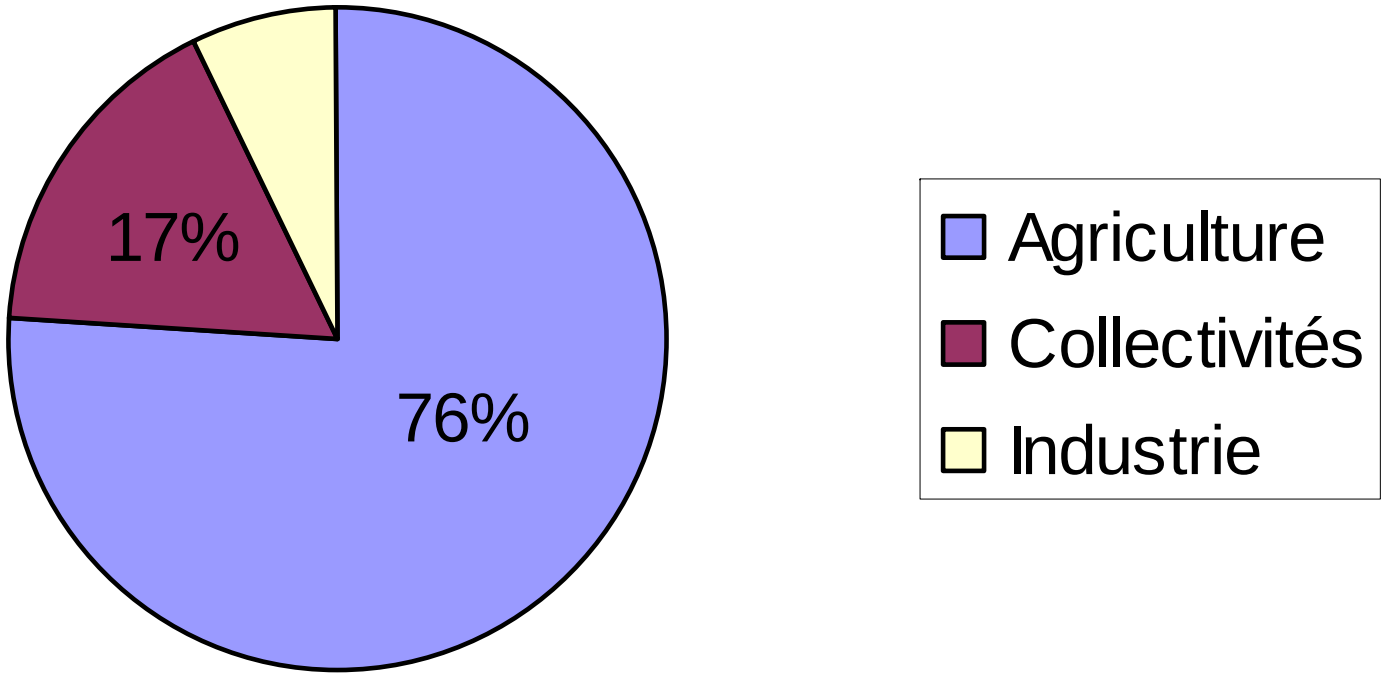


Increase of aquifer water table Niamey region




Rendement moyen mil / sorgho au Niger
Rendement mil / sorgho (kg'ha)
700
600
500
400
300
200
100
0
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
année

Prélèvements actuels de ressources en eau en Afrique de l'Ouest

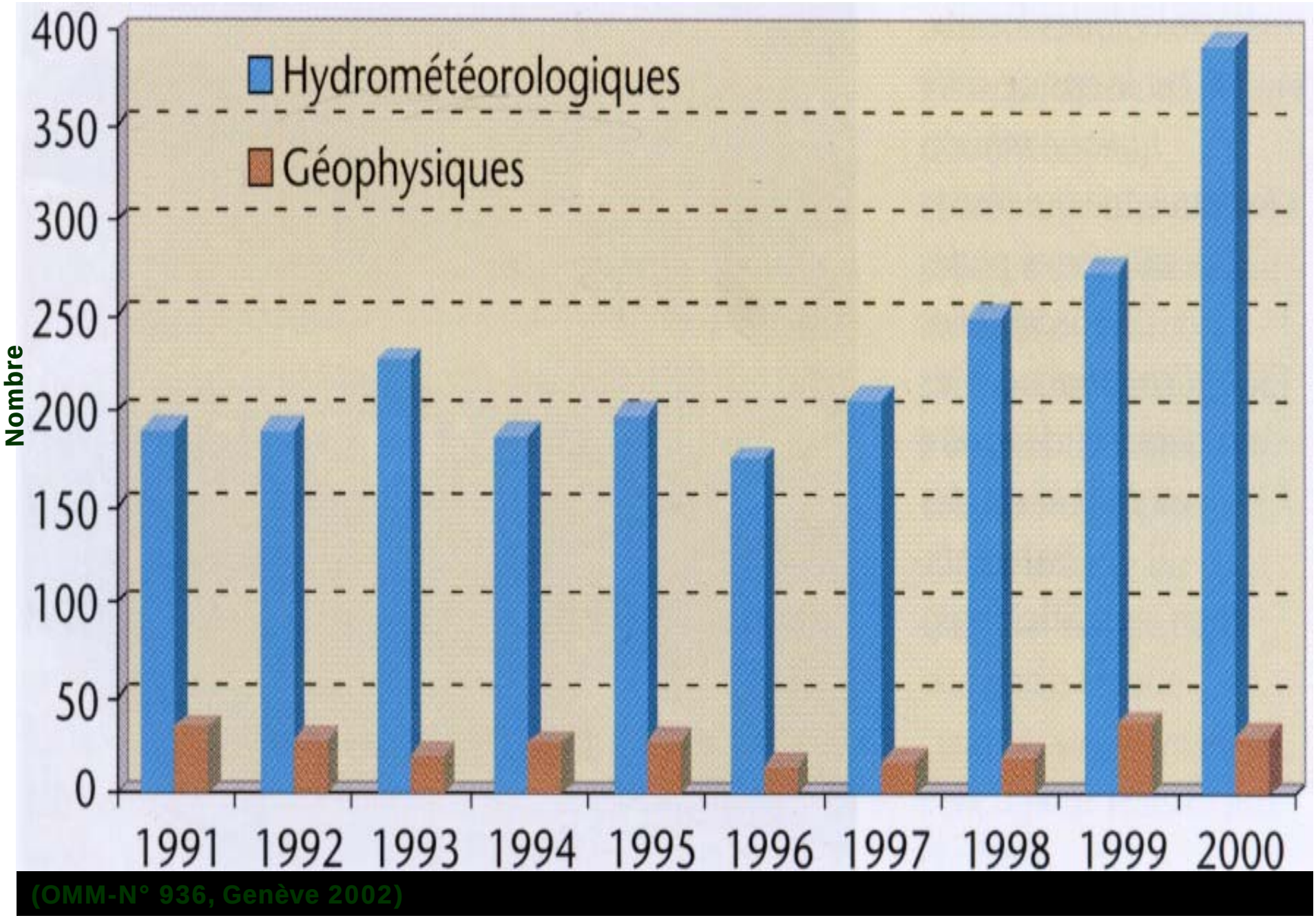


L’érosion côtière

Yenne sur mer

Rufisque

Evolution of disasters between 1991 and 2000, WMO 2002



(OMM-N° 936, Genève 2002)

Mozambique (Février et mars 2000) : Inondations provoquées par le passage des tempêtes tropicales **Elyne et Gloria** : 1 milliard de $ US de pertes


Niamey, août 2000

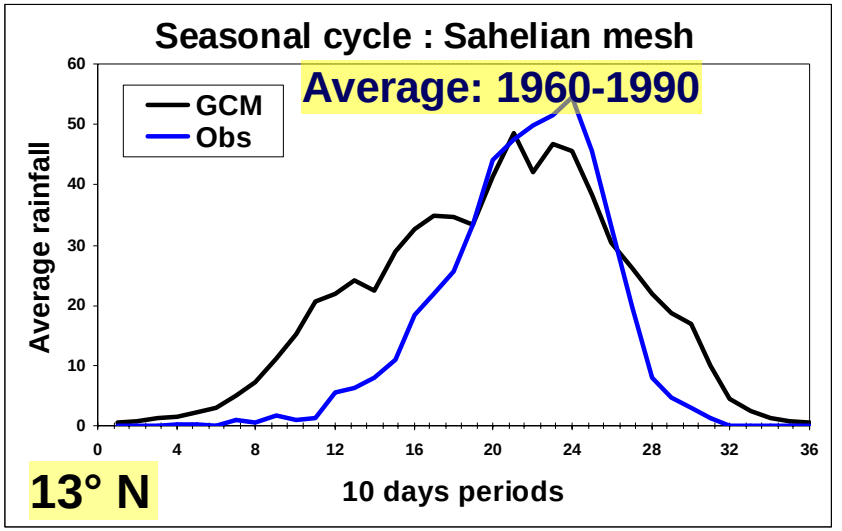
Inondation à Niamey - Août 2000

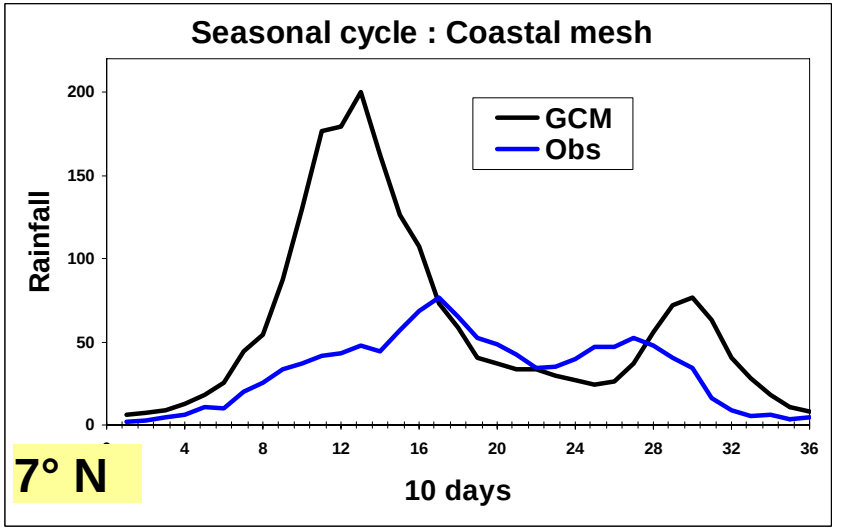
Seasonal cycle in a GCM

Wrong Seasonal Cycle

- Onset
- First Rainy Season on the coast

Is this due to a wrong forcing from the oceans or to a bad water budget over land (too much recycling) ?

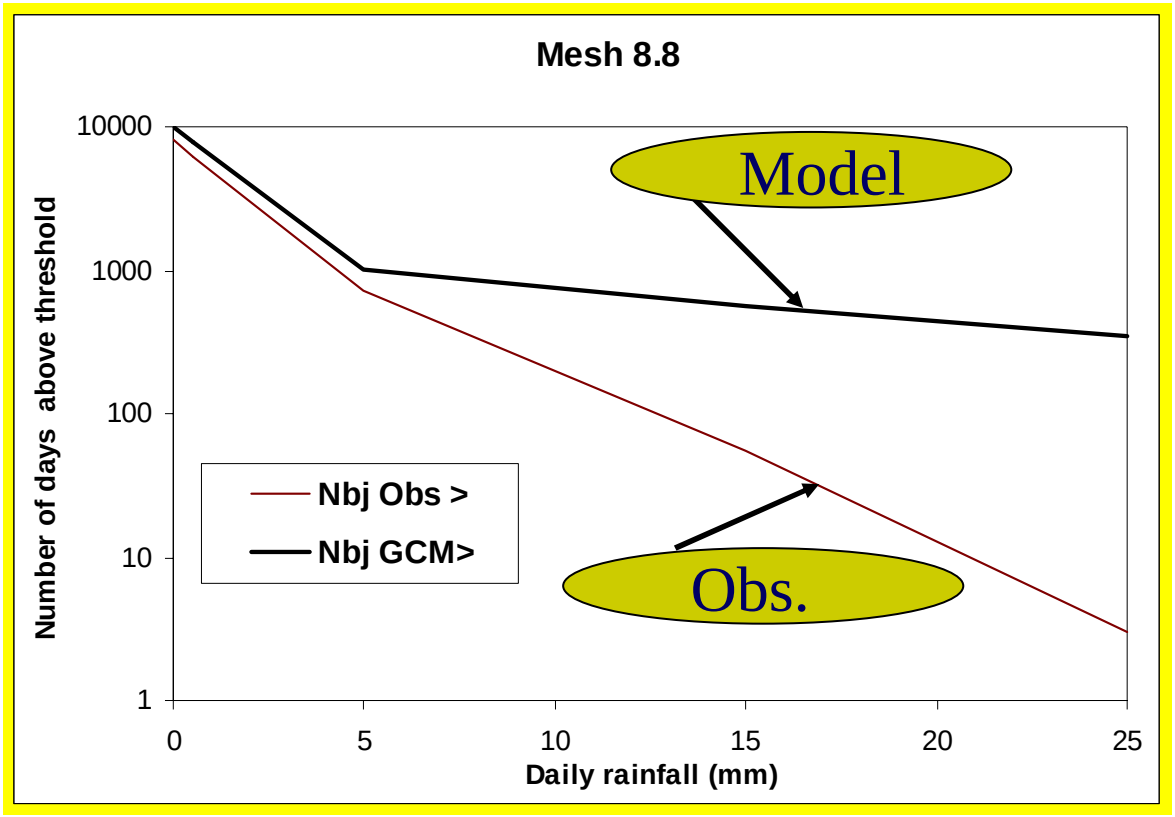




Daily rainfall in climate models

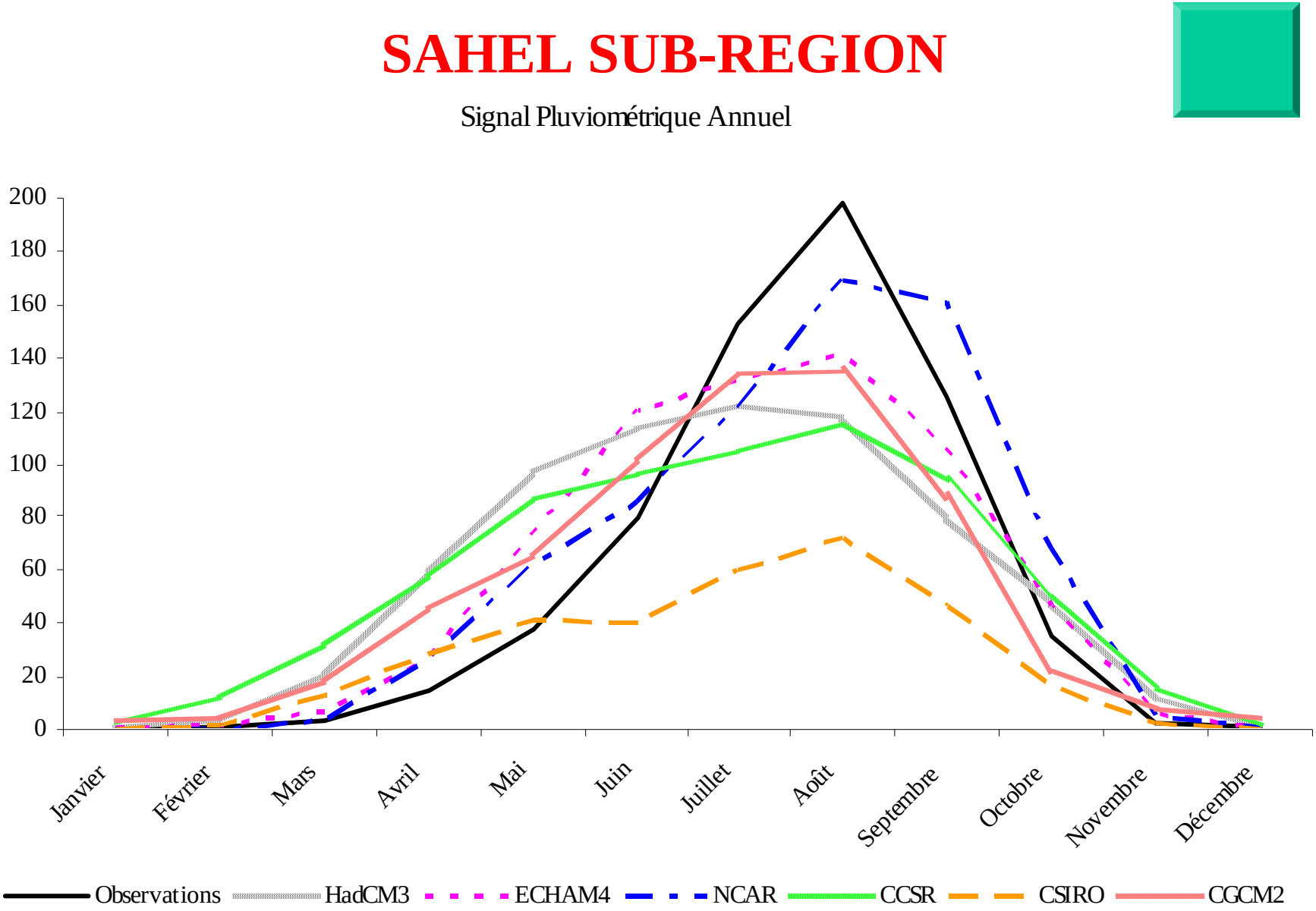
Average: 1960-1990

Daily rainfall in a GCM (1.65°*3.75°)

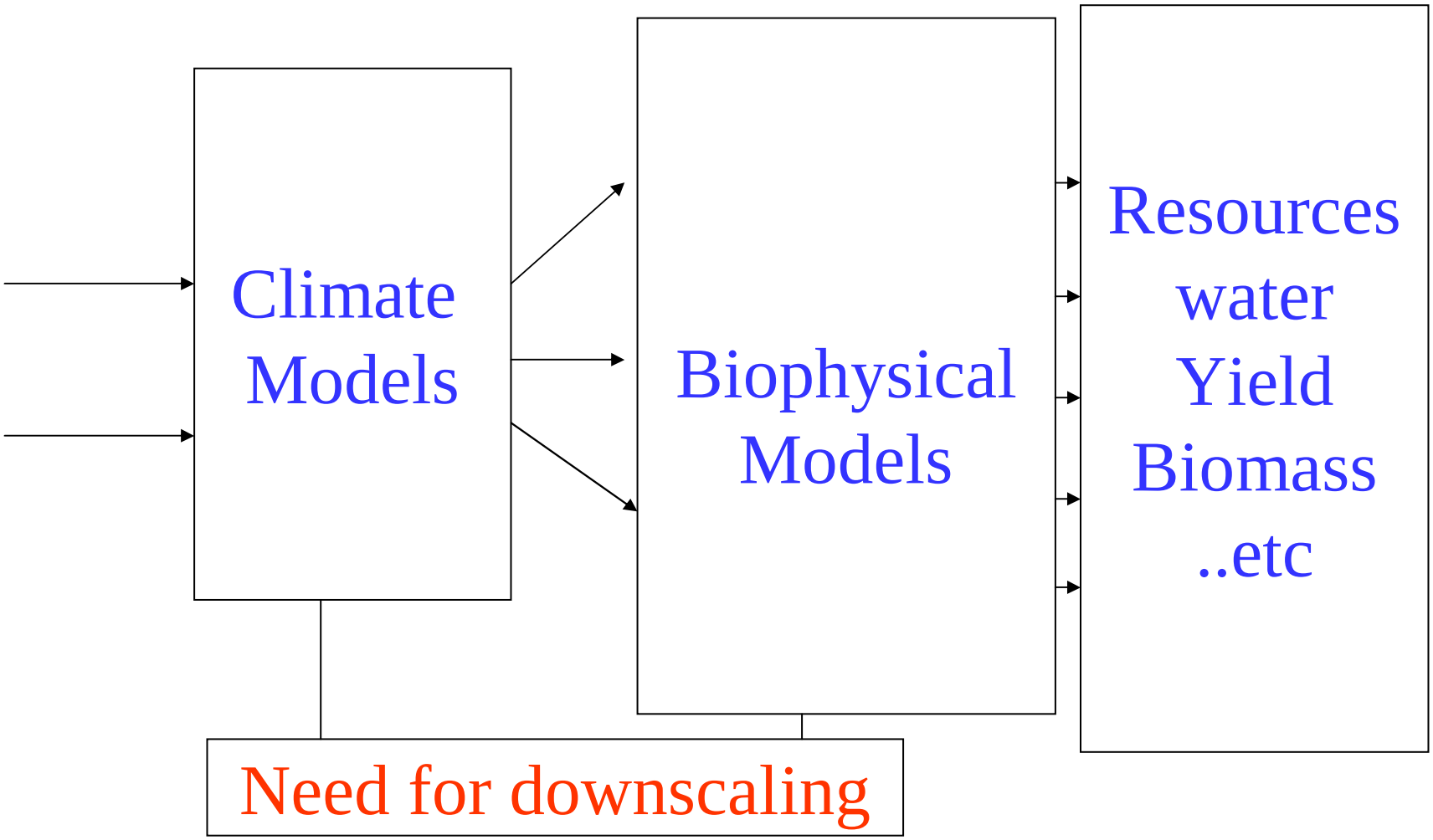


COMPARAISON OFF DIFFERENTS GCMs

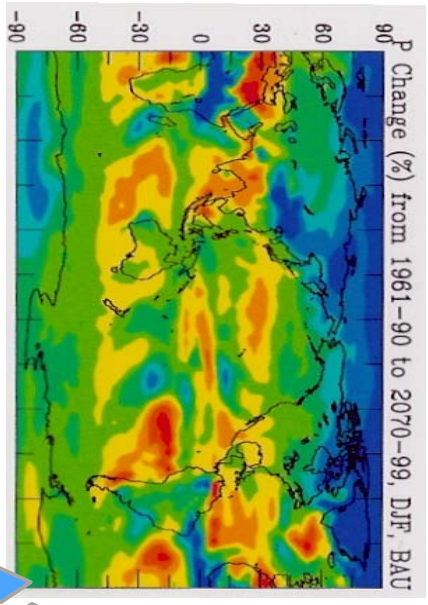
SAHEL SUB-REGION



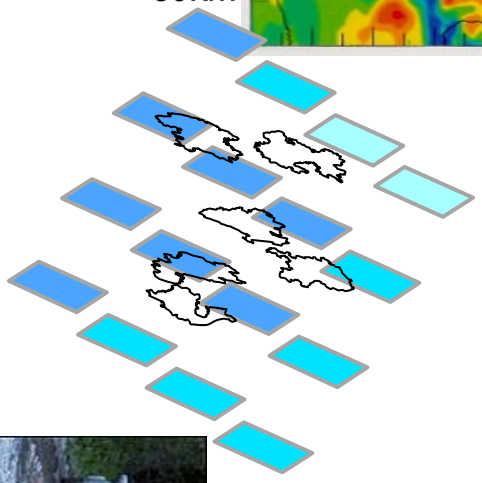
PROBLEMATIC OF CLIMATE IMPACT ASSESSMENT



300km



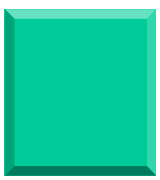
50km



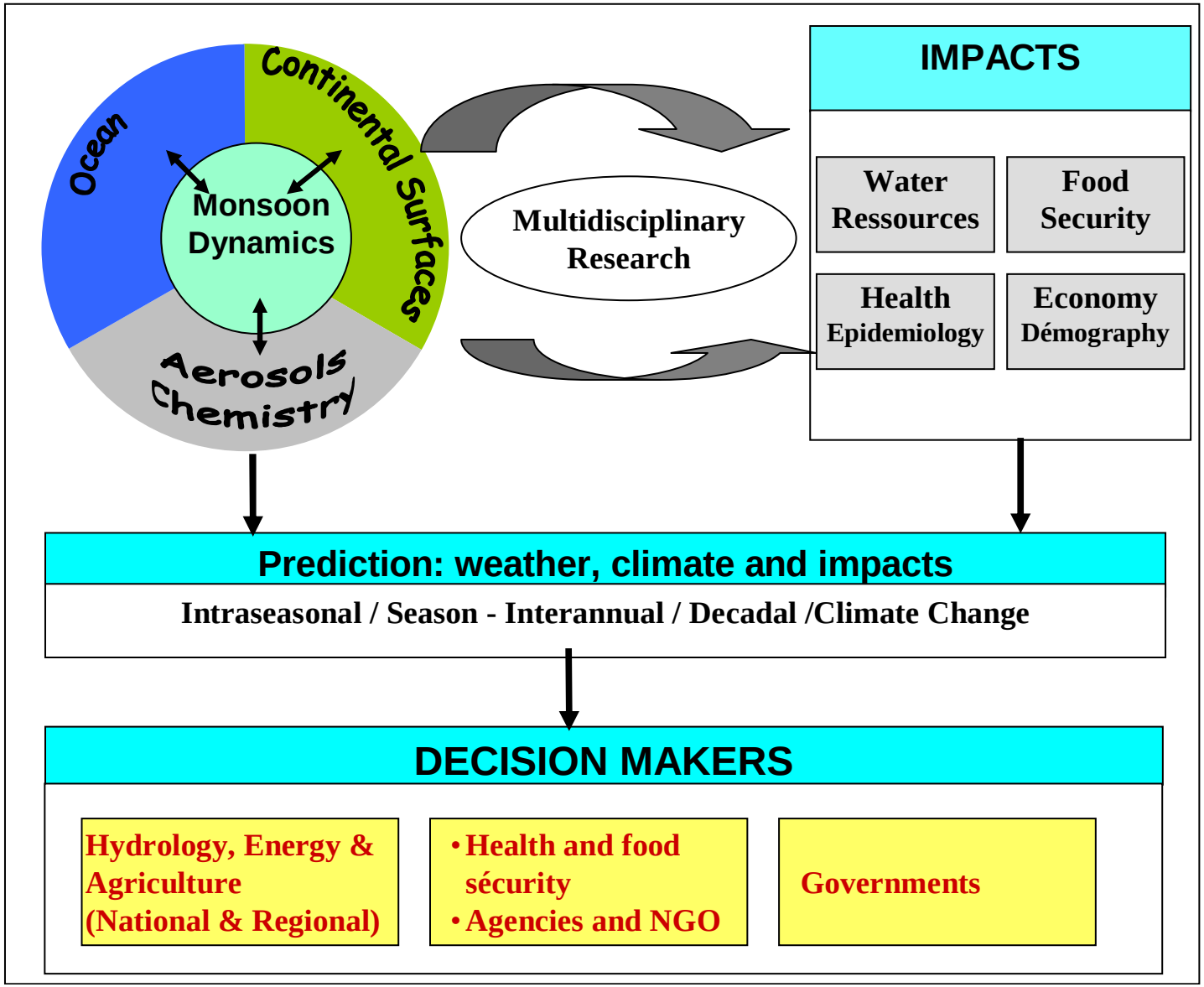
10km

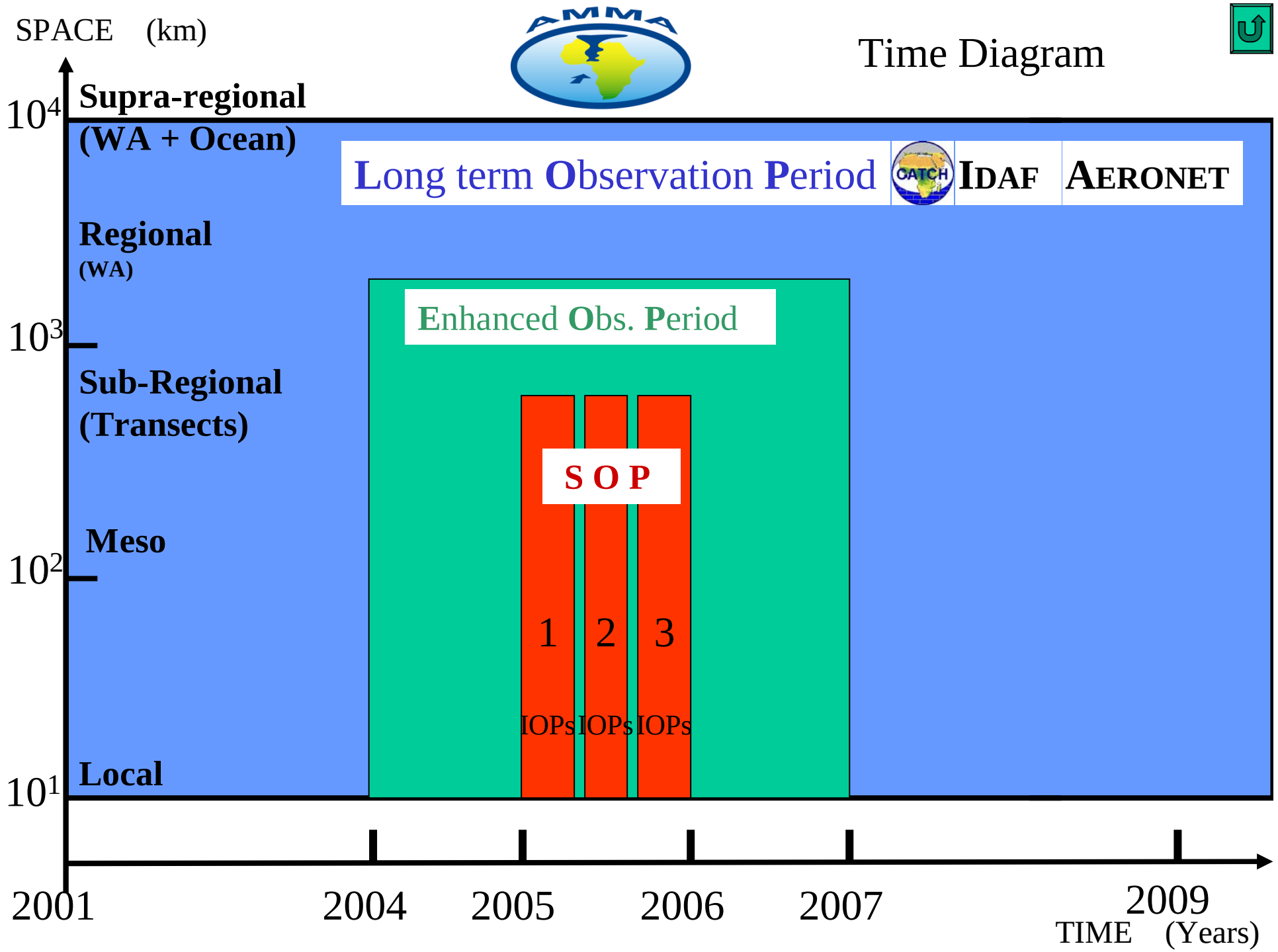
Point

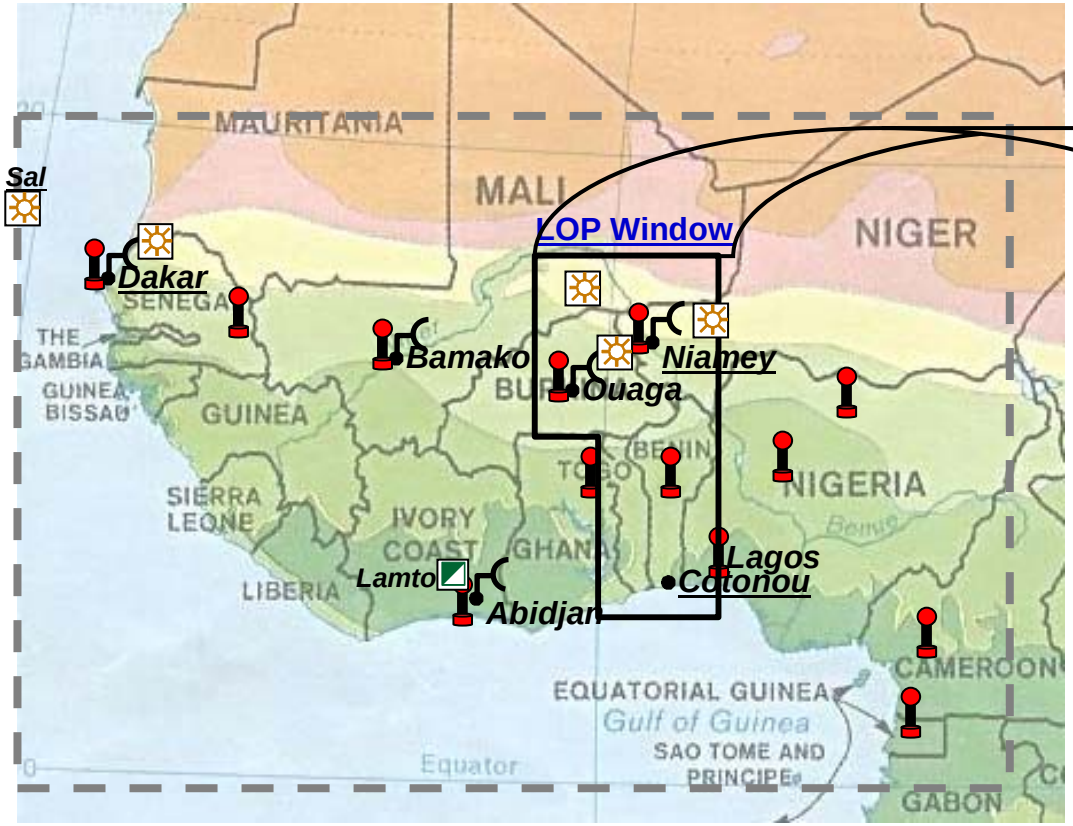
1m



AMMA General Scheme




SPACE (km)
Time Diagram
10^4
Supra-regional
(WA + Ocean)
Long term Observation Period
CATCH
IDAF
AERONET
Regional
(WA)
10^3
Enhanced Obs. Period
Sub-Regional
(Transects)
S O P
Meso
10^2
1
2
3
IOPs
IOPs
IOPs
10^1
Local
2001
2004
2005
2006
2007
2009
TIME (Years)

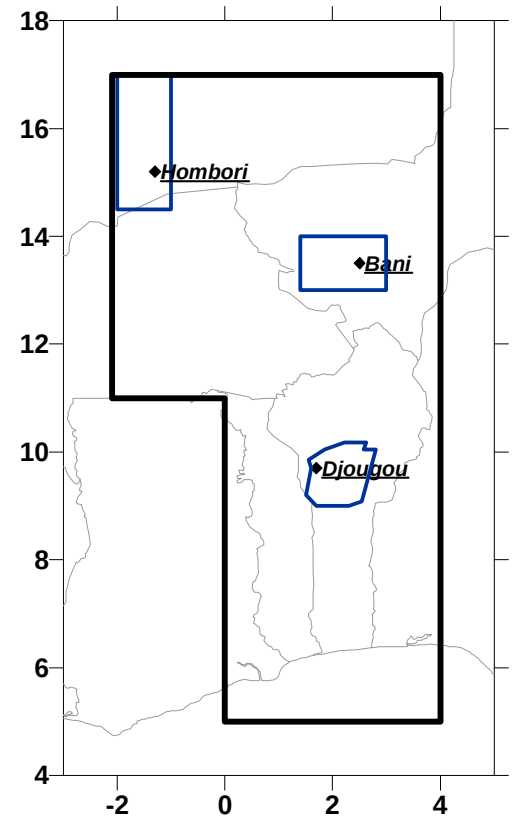


Radio-sounding

Weather Radar

Photometer

Niamey Aircraft operations



: mesoscale AMMA sites

◆ *Bani* : super-sites

GeoSFM (FEWS) : Stream Flow Model

Input data

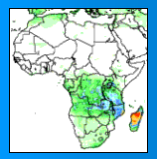
- daily rainfall (estimation, forecast)
- daily ETP
- Soil (FAO Map)
- Land Use / Land Cover (NOAA)
- DEM(1Km, NOAA)

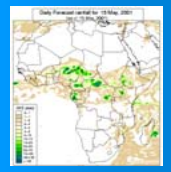
Output:

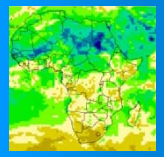
- daily discharge
- water level
- inundation areas

Stream Flow Model Diagram

Data

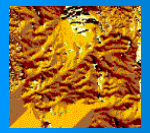

RFE


QPF


PET


Soil


LU/LC


DEM

Preprocessing

MAP

MAE

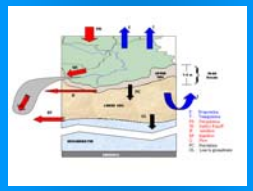
Basin

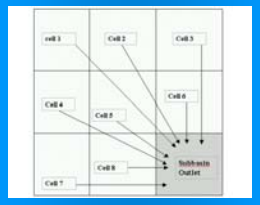
Linkage

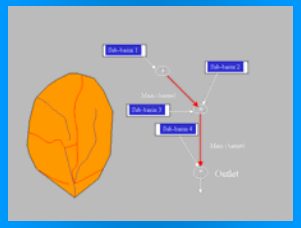
Routing Parameters

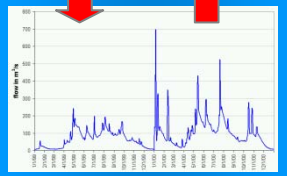
Soil Parameters

Stream Flow Model

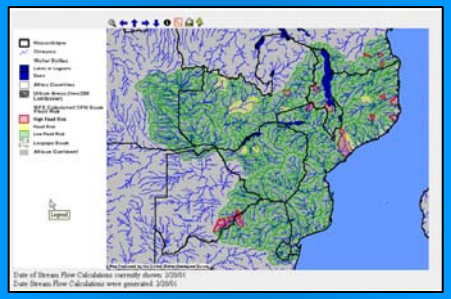

Water Balance

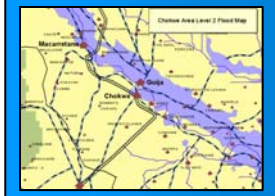

Lumped Routing

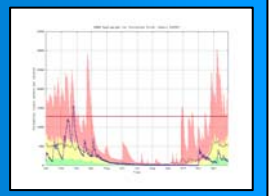

Dist. Routing


Updating

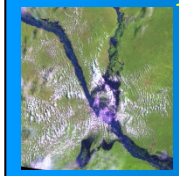
Output / Decision Support System

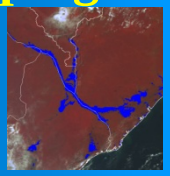






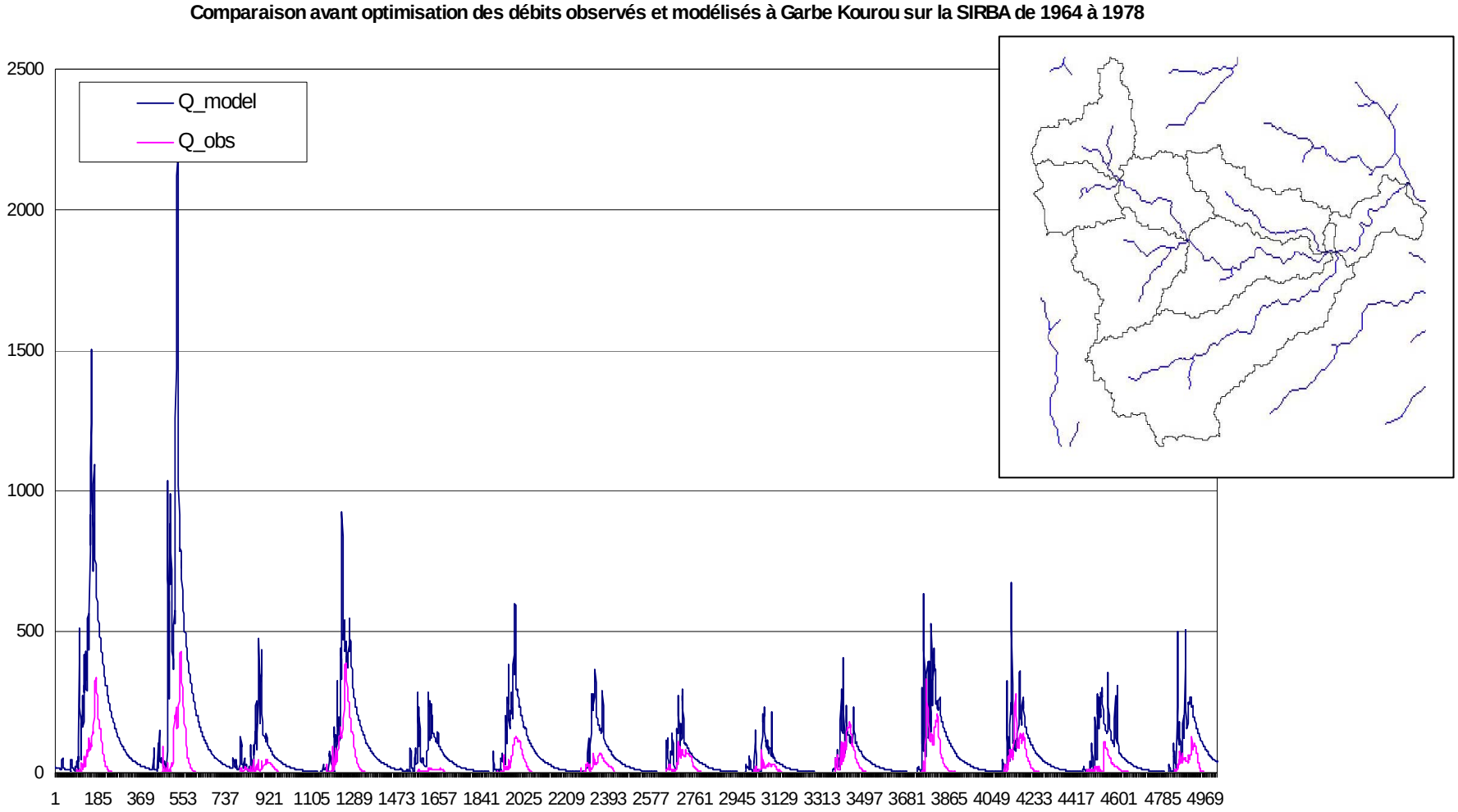
Flood Inundation Mapping





Landsat 7 SPOT

Applicatrion of GeoSFM to the basin of SIRBA (Burkina et Niger)



MODELISATION HYDROLOGIQUE

IMPORTANCE DE LA PLUIE COMME VARIABLE D'ENTREE SUR LA REPONSE HYDROLOGIQUE

Pluie variable déterminante

- Pluie moyenne sur le bassin ou par sous-bassin (global et sémi-distribué)
- Pluie sur forme de grille (cas des modèles distribués)

Toute erreur sur la pluie aura un impact important sur le débit en sortie du modèle

Pluie variable déterminante

Réseau de pluviomètres

sont généralement de faible densité

nécessité de spatialiser la pluie avec quelle méthode?

Estimation par télédétection

Avec quelle erreur?

Table 6.8: **Classification of improved and unimproved sanitation facilities**

Improved sanitation facilities	Unimproved sanitation facilities
Flush/pour flush to: piped sewer system septic tank pit (latrine)	Public or shared latrine
Ventilated Improved pit latrine	Pit latrine without slab or open pit
Pit latrine with slab	Hanging toilet/hanging latrine
Composting toilet	Bucket latrine
	No facilities (so people use any area, for example, a field)

Source: WHO/UNICEF, 2005; www.wssinfo.org

Table 6.7: **Classification of improved and unimproved drinking water sources**

Improved sources of drinking water	Unimproved sources of drinking water
Piped water (into dwelling, yard or plot)	Unprotected dug well
Public tap/standpipe	Unprotected spring
Tubwell/borehole	Vendor-provided water
Protected dug well	Tanker truck water
Protected spring	Surface water (river, stream, dam, lake, pond, canal, irrigation channel)
Rainwater collection	
Bottled water*	

*Bottled water is considered an 'improved' source of drinking water only where there is a secondary source that is 'improved'.

Source: WHO/UNICEF, 2005; www.wssinfo.org