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Hydrological Cycle and Climate Change: Understanding threats and making climate-smart investments in water sector

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Introduction

Last assessment report of the Intergovernmental Panel on Climate Change (IPCC) has concluded that there is increasing evidence that the earth's climate is changing and at an unprecedented rate (IPCC, 2007).
One of the important aftermath of this change is the acceleration of the hydrological cycle which imply increasing frequency and magnitude of extreme events (flood and drought), with embedded acceleration of glacial melt and see level rise threatening humans et ecosystems.


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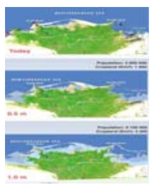
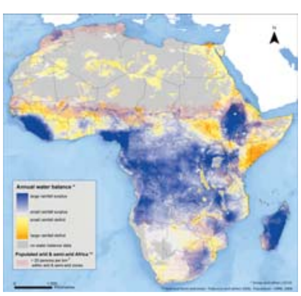
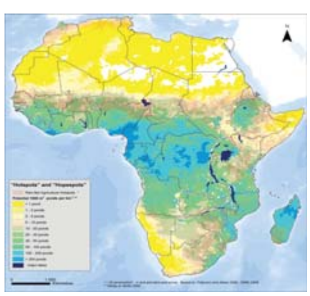

Potential impact of sea level rise: Nile Delta. Rising sea level would destroy weak parts of the sand belt, which is essential for the protection of lagoons and the low-lying reclaimed lands in the Nile delta of Egypt (Mediterranean Sea). http://www.grida.no/publications/vg/climate/page/3087.aspx


The images above show two perspective views of Mt. Kilimanjaro on Feb. 17, 1993 (top), and on Feb. 21, 2000 (bottom). These images were acquired by the Landsat 5 and Landsat 7 satellites, respectively. Credit: *Jim Williams, NASA GSFC Scientific Visualization Studio, Landsat 7 Science Team*

This unprecedented climate change will hardly affect developing countries especially in Africa because of their bio-physical and socio-economical vulnerabilities.
One of the crucial area of vulnerability in Africa is the water sector as "observational record and climate projections provide abundant evidence that fresh water resources are vulnerable and have the potential to be strongly impacted by climate change, with ranging consequences on human societies and ecosystems (Bates, et al. 2008).
Climate change could profoundly alter future patterns of both water availability and use, thereby increasing water stress globally especially in Africa. Future water availability, use, and investments will also depend on non-climatic drivers, including financial and sector conditions. Water investments are particularly vulnerable to impacts of climate change. The extent to which water investments are impacted by climate change will have ramifications that could extend to the economy and society at large (World Bank, 2009).


Annual water balance is an estimate of the available runoff after evapotranspiration—water that is potentially available for water harvesting. The red hatching overlaying the water balance map shows where population density of greater than 20 persons per km2 coincides with areas defined as arid or semi-arid.
(Source: Africa Water Atlas)


Areas of population density greater than 20 persons per km2 that coincide with arid and semi-arid zones are potential hotspots of vulnerability for water-constrained rain-fed agriculture (red hatch marks). Many of these areas have adequate runoff for fi lling small farm ponds, which can reduce vulnerability and improve food security (Senay and Verdin, 2004)
(Source: Africa Water Atlas)

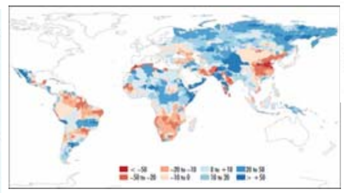
Projected Impacts on Hydrological Cycle and Water Resources in Africa

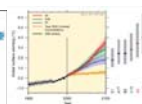
Several hydrological parameter are usually computed in order to capture the hydrological variability and give meaningful information for smart investment in water sector. These are: runoff, basin yield, high flows, low flows, base flows, net irrigation demand, deficit index etc.

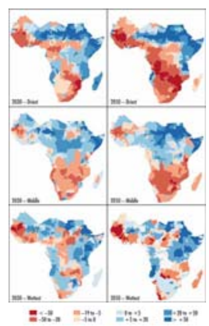
Table I: Changes in Key Hydrologic Variables

Key Variables	Observed Trends	Projections for 21st Century
Precipitation	[illegible]	[illegible]
Atmospheric water vapor content	[illegible]	[illegible]
Intensity of precipitation	[illegible]	[illegible]
Drought	[illegible]	[illegible]
Tropical cyclones	[illegible]	[illegible]
Glaciers and snow cover	[illegible]	[illegible]
Sea level	[illegible]	[illegible]

Source: IPCC, 2007


Projected percent change in runoff for 2030 (Source: World Bank, 2009)

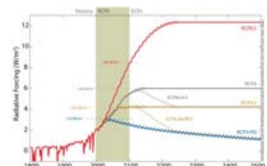

Multi-model averages and assessed ranges for surface warming
Solid lines are multi-model global averages of surface warming (relative to 1980-1999) for the scenarios A2, A1B, B1, shown as continuation of the 20th century
(Source: IPCC, 2007)


Projected percent change in runoff for 2030_Africa Region (Source: World Bank, 2009)

Towards better projections by improving climate scenarios: Representative Concentration Pathways (RCP)

A new type of pathway is being used for the next IPCC assessment — the Representative Concentration Pathway, or RCP. This defines credible pathways of atmospheric concentrations of CO2 and other greenhouse gases (taking account of the impact of aerosols) through time up to 2100.

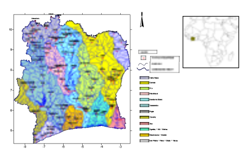

Approaches to the development of global scenarios: (a) previous sequential approach; (b) proposed parallel approach. Numbers indicate analytical steps (2a and 2b proceed concurrently). Arrows indicate transfers of information (solid), selection of RCPs (dashed), and integration of information and feedbacks (dotted). (Moss et al. 2009)

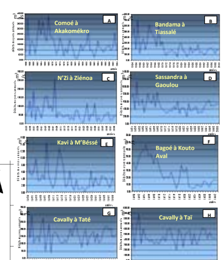


(Meinshausen et al. 2011)
Available at: http://www.pik-potsdam.de/~mmalte/rcps/graphics/RadiativeForcingRCPs.jpg

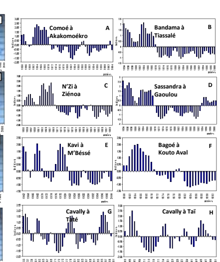
Global Anthropogenic Radiative Forcing for the high RCP8.5, the medium-high RCP6, the medium-low RCP4.5 and the low RCP3-PD. In addition, two supplementary extensions are shown, connecting RCP6.0 levels to RCP4.5 levels by 2250 (SCP6TO45) or RCP45 levels to RCP3PD concentrations and forcing (SCP45to3PD).

Case study: Impacts of Climate Changes on runoff in Côte d'Ivoire

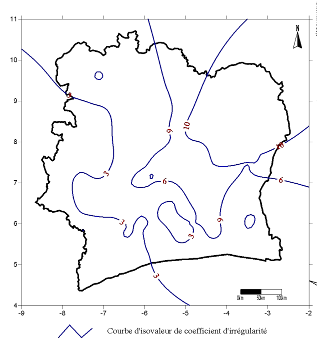




Runoff evolution of several rivers in Côte d'Ivoire



Flood Index of several rivers in Côte d'Ivoire



The studies on trend and rupture in runoff data of Côte d'Ivoire in the framework of the elaboration of the Hydro-Climatic Atlas of Côte d'Ivoire concluded that there are 105 downward trends against 7 upward trends detected by Man-Kendall and Linear Regression tests in five (*MAXAN, MINAN, MOYAN, POT1 and POT3*) runoff type of series.
Ruptures in hydro-meteorological data detected by Buishand and Pettitt Tests occurs around 1970 like in many area of Western and Central Africa.

Flood frequency analysis have permitted to highlight the regularity of runoff by using the inter-annual irregularity coefficient K_3 (Roche, 1963). The more K_3 is close to 1 the more the runoff is regular.

Photo Credits: 1) http://careandvalue.files.wordpress.com/2009/04/drought-africa2.jpg?w=221&h=300
2) http://iphonasia.com/wp-content/uploads/2008/12/Perfect-Storm-in-Social-Network-acceptance.jpg
3) http://www.gibbsmagazine.com/Floods%20of%20SA.jpg