This material is shared as a learning resource to promote awareness and good practice in the provision, use and management of water resources for sustainable social and economic development and maintenance of African ecosystems.

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Hydro-climate services for Water Security

Abou Amani, Anil Mishra and Koen Verbist
Hydrological systems and water scarcity section
UNESCO International Hydrological Programme (IHP)

7th Africa Water week, Libreville, Gabon, 30th October 2018
“the capacity of a population to safeguard access to adequate quantities of water of acceptable quality for sustaining human and ecosystem health on a watershed basis, and to ensure efficient protection of life and property against water related hazards — floods, landslides, land subsidence and droughts.”

UNESCO-IHP definition of Water Security
Hydro-climate Services

Hydro-climate information for decision making

- High quality data on hydro-climate variables (Temp, Precipitation, discharge, sediment, soil moisture, winds,...etc)
- Maps on risk, vulnerability, forecast, long term projection, scenarios

Providing decision makers with user friendly and meaningful information
Improve knowledge and innovation to address water security challenges.

Axis 1: Mobilizing international cooperation to improve knowledge and innovation to address water security challenges.

Axis 2: Strengthening the Science-Policy interface to reach water security at local, national, regional and global levels.

Axis 3: Enhancing policy advice to reach water security at local, national, regional and global levels.
Water sciences can support smart decision making

Science AND Policy vs Science for Policies

Credible data is needed to underpin sector advocacy, stimulate political commitment, inform decision making and trigger well-placed investments towards optimum health, environment and economic gains.

Knowledge brokers are key to communicating scientific findings to decision-makers, and to developing tools and mechanisms to translate science into practical solutions.
How does IHP support smart decision-making?

- Enhancing networking for knowledge sharing
- Promoting regional and international cooperation
- Supporting capacity building and education to empower local communities
- Developing information, tools & methodologies
GWADI-Near real time estimated rainfall data

Drought and flood Monitoring and Management

Climate risks identification: Drought Atlas and floods mapping

Design of hydraulic infrastructures

Climate change impact assessment
Networks for global networking and knowledge sharing between international entities to:

- Improved understanding of hydrological systems and water management needs in arid areas, river basins, etc. and surveys drought management and flood hazards;
- Develops capacity building to better understand and respond to floods hazards while taking advantage of their benefits;
- Promote regional and international cooperation on droughts and floods issues:
  - Focus on research, information networking, education and training to empower communities.
Knowledge of hydrological systems: G-WADI Geo-Server: real time rainfall data

**Geo-Server** that provides access to very high resolution (0.04) satellite-based quasi-global precipitation products in near real time to worldwide users.

**Potential area for cooperation**

**Algorithm**

**Web Services**

**Applications**

- Drought Management
- Flood Management
- Water Resources

**Sharing data** and **exchanging experience** to support research and sound water management
G-WADI Geoserver
Pakistan floods, 2010

Near-real-time high resolution Satellite-based Observations of rainfall: Pakistan Flooding

UNESCO-IHP launched a major project in cooperation with the Government of Japan that aims to improve the flood management using early warning systems of Pakistan, and to conduct risk mapping of flood plains along the Indus River.

http://chrs.web.uci.edu/PakFlooding.html
G-WADI Geoserver application in Namibia - Science communication

Satellite images over the last 24 hours showed isolated showers over the north-central, northeast and eastern parts of Namibia.

G-WADI-rainfall accumulation for the past 24 hours preceding 08h00 on 26.01.2018
Both over- and underestimation is removed from the satellite precipitation estimates.

G-WADI Geoserver

Importance of monitoring to calibrate remote sensing datasets
Usage of CHRS’s G-WADI Geoserver

CHRS User Statistics

Overall CHRS Homepage rRain RainSphere Data Portal CONNECT
Total Visits: 752,123 since 01-Jan-2010
Countries: 199 countries registered

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Data Download

User Visit
Data exchange tools as decision support systems to reinforce climate resilience
Providing Tools to Identify Climate Risks

African Flood and Drought Monitor

West Africa
AGRHYMET

Eastern Africa
ICPAC

Southern Africa
WATERNET

Lake Chad Basin

User Interface: http://stream.princeton.edu
African Drought and Flood Monitor: monitoring both flood and drought in Sud-Sahara Africa
Towards an Integrated Drought Risk Management

Latin American and Caribbean Drought Atlas

Africa Drought Atlas in preparation

- Training sessions were organized to capacitate different LAC member countries on the methodology of the Drought Atlas.

- During 2015, the Latin American Drought Atlas was finalized and most countries (17) of Latin America and a significant set of Caribbean Countries (4) were supported in that development.

The online Drought Atlas

Provides stakeholders with a tool to identify their drought hazard for any location in the Region of Latin America and the Caribbean, bringing the information at the level where it is most needed for decision making.

http://www.climatedatalibrary.cl/CAZALAC/maproom/Historical/index.html
Flood Risk Assessment

Integrated Flood Analysis System (IFAS)

Ensemble Flood Prediction

Rainfall-Runoff-Inundation (RRI) Model

Flood Impact on Rice Production

Rice Production Fragility Curve

Global data: topography, land use, etc.

Ground-gauged and satellite rainfall

Courtesy of JAXA

Model creation

Runoff analysis

River discharge, Water level, Rainfall distribution

Note: Green line and blue line are overlapped

Vegetative Stage

Maturity Stage

Ripening Stage

Ensemble flood forecast

Observation

High resolution observation

Generate perturbation

EnKF analysis

Regional ensemble
For arid and semi-arid basins (Sahelian climate)

Increase in discharge quantiles for present conditions

Nakambe river at Wayen
(Burkina Faso)
(20 800 km²)

Data from DGRE, Burkina Faso
CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

P. C. D. Milly,* Julio Betancourt,† Malin Falkenmark,* Robert M. Hirsch,* Zbigniew W. Kundzewicz,‡ Dennis P. Lettenmaier,* Ronald J. Stouffer*†

Systems for management of water throughout the developed world have been designed and operated under the assumption of stationarity. Stationarity—the idea that natural systems fluctuate within an unchanging envelope of variability—as a foundational concept that permeates training and practice in water-resource engineering. It implies that any variable (e.g., annual streamflow or annual flood peak) has a time-invariant (or 1-year-periodic) probability density function (pdf), whose properties can be estimated from the record. Under stationarity, pdf estimation errors are acknowledged, but have been assumed to be reducible by additional observations, more efficient estimators, or, regional or paleohydrologic data. The pdfs, in turn, are used to evaluate and manage risks to water supplies; waterworks; and floodplains; annual global investment in water infrastructure exceeds U.S. $550 billion (1).

The stationarity assumption has long been compromised by human disturbances in river basins. Flood risk, water supply, and water quality are affected by water resources, infrastructure, channel modifications, drainage systems, and land-cover and land-use changes. Two other (sometimes indistinguishable) challenges to stationarity have been externally forced, natural climate changes and low-frequency, interannual variability (e.g., the Atlantic multidecadal oscillation) enhanced by changes in the thermohaline circulation of the ocean and ice sheets (2, 3). Planners have tools to adjust their analyses for known human disturbances within river basins, and justifiably or not, they generally have considered natural change and variability to be sufficiently small to allow stationarity-based design.

In view of the magnitude and ubiquity of the hydroclimatic changes apparent now under way, however, an assumption of stationarity is dead and should no longer serve as a central default assumption in water-resource risk assessment and planning. Finding a suitable successor is crucial for human adaptation to changing climate.

How did stationarity die? Stationarity is dead because substantial anthropogenic climate change of Earth's climate is altering the means and extremes of precipitation, evaporation, transpiration, and rates of discharge of rivers (4–7) (see figure, above). Warming augments atmospheric humidity and water transport. This increases precipitation, and possibly flood risk, where prevailing atmospheric water-vapor fluxes converge (8). Rising sea level induces gradually heightened risk of contamination of coastal freshwater supplies. Glacial meltwater temporarily enhances water availability, but glacier and snow-pack losses diminish natural seasonal and intrannual storage (7).

Anthropogenic climate warming appears to be driving a poleward expansion of the subtropical dry zone (8), thereby reducing runoff in some regions. Together, circulatory and thermodynamic responses largely explain the picture of regional gainers and losers of sustainable freshwater availability that has emerged from climate models (see figure, p. 574).

Why now? That anthropogenic climate change affects the water cycle (9) and water supply (10) is not a new finding. Nevertheless, sensible objections to discarding stationarity have been raised. For a time, hydroclimate had not demonstrably exited the envelope of natural variability and/or the effective range of optimally operated infrastructure (11, 12). Accounting for the substantial uncertainties of climatic parameters estimated from short records (13) effectively hedged against small climate changes. Additionally, climate projections were not considered credible (12, 14).

Recent developments have led us to the opinion that “the time has come to move beyond the wait-and-see approach. Projections of runoff changes are bolstered by the recently demonstrated retroactive skill of climate models. The global pattern of observed annual streamflow trends is unlikely to have arisen from unforced variability and is consistent with modeled response to climate forcing (15). Paleohydrologic studies suggest that small changes in mean climate might produce large changes in extremes (16), although attempts to detect a recent change in global flood frequency have been equivocal (17, 18). Projected changes in runoff during the midcentury lifetime of major water infrastructure projects began now are large enough to push hydroclimate beyond the range of historical behavior (19). Some regions have little infrastructure to buffer the impacts of change.

Stationarity cannot be revived. Even with aggressive mitigation, continued warming is very likely, given the residence time of atmospheric CO₂ and the thermal inertia of the Earth system (4, 20).

A successor: We need to find ways to identify nonstationary probabilistic models of relevant environmental variables and to use these models to optimize water systems. The challenge is daunting. Patterns of change are complex; uncertainties are large; and the knowledge base changes rapidly.

Under the rational planning framework advanced by the Harvard Water Program (21, 22), the assumption of stationarity was
A cascade of uncertainty proceeds from different socio-economic and demographic pathways, their translation into concentrations of atmospheric greenhouse gas (GHG) concentrations, expressed climate outcomes in global and regional models, translation into local impacts on human and natural systems, and implied adaptation responses.

Wilby and Dessai, 2010
Climate Risk Informed Decision Analysis (CRIDA)

A bottom-up approach to utilize the information in the GCMs

Traditional Approach

1. Downscale a few climate model projections
2. Generate a few water supply series
3. Determine whether system performance is acceptable for these series.

Decision Scaling

1. Determine the vulnerability domain
2. Map climate domain onto vulnerability domain
3. Determine climate risks to project performance

\[
\text{Risk to ENB} = \sum_{\omega} \text{Impact} \times \text{Probability}
\]

Expected Net Benefits (ENB)
Thank you!

https://en.unesco.org/themes/water-security/hydrology