The Role of the Atlantic Ocean in Modulating the Recent Multi-Decadal Drought of East Africa

Wednesday, August 5th 2015

Fredrick Semazzi
North Carolina State University

Co-Investigators: Bin Liu, Lian Xie, Kara Smith, Michael Angus, Masilin Gudoshava, Rowan Argent, Xia Sun, Stefan Liess and Atreyee Bhattacharya
OUTLINE

Background

- Evidence of multi-decadal East African rainfall drought and its impacts
- Relationship Between AMO and the Onset of the Indian Summer Monsoon
- Motivation from computer science and climate science collaborative study on Atlantic hurricanes
- Controversy Regarding Cause of the Multi-decadal Decline (Persistent Drought)

Expedition Research

- Relationship of Multi-Decadal Drought (MDD) with Global SST (GSST)
- AMO-Induced Teleconnections
- Integrated Conceptual Model of AMO Teleconnection Mechanisms

Conclusions
Background
Lake Victoria Basin

- LVB is the social-economic nerve center for EA (Burundi, Rwanda, Kenya, Tanzania, Uganda) – 30 to 40 million

- Mainly rain fed agricultural economy with LV supplying fish as a major part of the diet

- Lake Victoria also provides hydroelectric energy and relatively inexpensive form of transportation

- Geopolitical significance of LVB as the source of the White Nile
Low-pass filtered rainfall (>10yr), MAM average over Greater Horn of Africa

- Persistent past decline & projected reversal and increase
- Phenomenon known as the East African climate change paradox
- Could have profound implications on LVB sustainable development for more than 35 - 40 million people

(David Rowell, UKMO, 2013)
East African Drought (CRU Rainfall)

Also evident in regional lakes (Karpatne et al, 2015)

The **primary scientific challenge** therefore is to **reduce** the present high levels of **uncertainty** associated with the paradox problem to ascertain,

(i) **whether** indeed the **reversal** will **occur**,  

(ii) the **timing** of when it will materialize and  

(iii) **whether these two factors** will be **determinable** at acceptable levels of **confidence** to inform the **management** of the leading regional climate sectors.

Coordination & policymakers: seamless flow of knowledge/information from the international level (GHP) level, to the regional level (HYNEWS), to the national level (NMHS), to the sub-national district level, to the county level, to the sub-county level, to the parish level and finally to the village level, which comprises only a handful of households

**Tools:** Hi-Resolution ReASM with comprehensive physics; New UKMO 4km resolution GCM

**Observations:** Regional observational campaign including lakes

**Users:** Primary climate sensitive social-economic sectors in Eastern Africa include agriculture, fisheries, water resources, tourism, energy, urban development, transportation, bio-diversity conservation, and disaster risk management.
HyVic Project
Proposed GEWEX RHP Hydroclimate Project for Lake Victoria Basin (HYVIC)

Terrestrial Regional North American Hydroclimate Experiment (TRACE)

GEWEX is a core project of WCRP on Global Energy & Water Exchanges

GHP: A GEWEX Hydroclimate Panel

Regional water cycles
WCRP Organization

Joint Scientific Committee

Joint Planning Staff

Modeling Advisory Council

Data Advisory Council

**Working Groups on:** Coupled Modelling (WGCM), Regional Climate (WGRC), Seasonal to Interannual Prediction (WGSIP), Numerical Experimentation (WGNE)

---

**CLiC**
- Cryosphere-Climate Interactions
- Ocean-Atmosphere Interactions

**CLIVAR**
- Regional Climate Information
- Sea-Level Rise and Regional Impacts
- Cryosphere in a Changing Climate
- Changes in Water Availability
- Clouds, Circulation and Climate Sensitivity
- Climate Extremes

**GEWEX**
- Land-Atmosphere Interactions
- Troposphere-Stratosphere Interactions

**SPARC**
- Troposphere-Stratosphere Interactions

---

**HYVIC**
HyVic Research Agenda
HyVIC Science Plan Components

HyVIC Research Theme-1: Translational Research Interface with Applications
HyVIC Research Theme-2: Severe Weather and Water Currents (collaboration with WWRP-LVP)
HyVIC Research Theme-3: Lake Victoria Basin Hydrologic Budget
HyVIC Research Theme-4: Climate variability and model development
HyVIC Research Theme-5: Observation of the Hydroclimatological System

(Customized from GFCS)
HyVic Regional Earth System Model (REaSM)

Regional Atmosphere Module

Rainfall & Temperature

Land Surface Module

Crop Module

Crop Area

Vegetation Area Module

Forestry Area

Population Module

Food

Energy

Fish

Water

Lake Victoria Module

Primary Productivity Module

Fish Module

Hydrology Module

Global Model

Geospatial Analytics

Climate Projections

Applications

Communication
HyVic Greater Domain and Multi-Decadal drought

A recent and abrupt decline in the East African long rains

Anomalous MAM rainfall (from GPCP; mm/day)
- (Lyon and DeWitt, 2012)
Major Controversy Regarding Cause of the Multi-decadal Decline (Persistent Drought)

Williams and Funk (2011): Anthropogenic warming forced rapid warming of Indian Ocean SSTs; extended the warm pool and Walker circulation westward; resulting in a subsidence anomaly and drying over East Africa

• Lyon and DeWitt (2012): On the contrary, linked the decline with a shift to warmer SSTs over the western tropical Pacific and cooler SSTs over the central and eastern tropical Pacific

• Lyon et al. (2014): More recently, have attributed the shift to natural multidecadal variability in the Pacific (modeling)


• Semazzi et al (2015; Nature Communications, in revision): The decadal variability of the cessation is dominated by AMO stationary Rossby wave; AMO contribution on MAM total season is same order of magnitude but less than Indo-Pacific
Expedition Research
Motivation from Computer Science and Climate Science Collaborative Study on Atlantic Hurricanes
Assessed correlation and contribution to the explained variance of Atlantic hurricane count of the **GHA hotspot** with respect to traditional climate indices in June.

![Graph showing correlation and contribution to explained variance](image)

* indicates statistically significant correlation with $p < 0.05$
Genesis phase of AEW disturbances
(Ethiopian Highlands?)

A conceptual model of generation of cyclonic vorticity perturbations and convective cloud clusters preceding the pre-Debby (2006) AEW-MCS system.
Alps Generated Stationary Rossby Wave Train in the Westerlies

Hypothesis
V-Wind anomalies at 500mb
Hypothesized Geopotential Anomalies at 500mb
Regional Multi-Decadal Variability
MAM & May GPCC & CRU EOF1 Time series; GPCC & CRU regional Average

NOTE: (i) robustness, and (ii) LR multi-decadal decline.
EOF1 Loading for M, A, M & MAM
Relationship of Multi-Decadal Drought (MDD) with Global SST (GSST)
May AMO and East Africa Average Rainfall
AMO-Induced Teleconnections
May EOF1 (AMO-like) geopotential at 300mb Composite (negative/positive AMO/EA rainfall)

Semazzi et al; Nature Communication (2015, in revision)
May EOF1 (AMO-like) geopotential at 300mb Composite (positive/negative AMO/EA rainfall)

Semazzi et al; Nature Communication (2015, in revision)
May Anomaly flow, 1951-2010 Composites

- Wet Composite, 300mb
- Dry Composite, 300mb
- Wet Composite, 850mb
- Dry Composite, 850mb
AMO Link Between Africa and Indo-Asia
Reversal of the Cross-Equatorial Low Level Flow

AMO Affects Cessation of East African Long Rains and Onset of the Indian Monsoons
EA domain rainfall EOF1 (AMO-like mode) vertical cross-sections for the vertical motion

Low Rainfall

High Rainfall
Integrated Conceptual Model of AMO Teleconnection Mechanisms
Combined Contributions

**Wet Composite-Cold AMO Phase**
- drier at 850 mb

**Dry Composite-Warm AMO Phase**
- wetter at lower levels
Conclusions

• We have tracked a path for the connection between the Atlantic Ocean and the multi-decadal variability of the long rains of east Africa including the ongoing decline.

• The analysis indicates high correlation between the May rainfall and North Atlantic SST which in turn is the Atlantic MO.

• Composites of the geopotential based on these time series (AMO, NA SST, EA/May rainfall) reveals a distinct poleward and equatorward Rossby wave train as a primary teleconnections mechanism.
GHA Hotspot Evaluation with respect to traditional climate indices

Assessed correlation and contribution to the explained variance of Atlantic hurricane count of the GHA hotspot with respect to traditional climate indices in June.

* indicates statistically significant correlation with $p < 0.05$
Steps to Attribution

Exploratory Analysis
- multivariate relationships
- modes of behavior

Analysis within a Dynamical Framework
- budgets, simplified models
- physical mechanisms

Model Experimentation
- reanalysis provides various levels of constraints
Funding

- Estimated target funding for 4 years: at least $50 Million

- Funding Status

(i) **NERC-UK**: Integrating Hydro-Climate Science into Policy Decisions for Climate-Resilient Infrastructure and Livelihoods in East Africa (HyCRISTAL) – £4 million ($3.38 million) awarded

(ii) **DFID-UK**: Research to Understand and Improve Navigation Safety and the Exploitation of Climate-Sensitive Natural Resources over Lake Victoria Basin—£35m ($38 million) awarded (£19m for RDEL and £16m for CDEL)

(iii) **NSF-US** – $1 million (in preparation)

(iv) **KOICA (South Korea)** – $1.5 million (in preparation)
Acknowledgements

Dr. Nagiza Samatova: Primary source of motivation

Co-Investigators (Atlantic Ocean Forcing (Study)): Bin Liu, Lian Xie, Kara Smith, Michael Angus, Masilin Gudoshava, Rowan Argent, Xia Sun, Stefan Liess and Atreyee Bhattacharya

Co-Investigators (HyVic): HyVic IPC; HyCristal Co-PIs; HyNEWS Co-PIs

Funding: NSF, DFID/UK, NERC/UK
There are enormous challenges ahead
But together we can make it!

Thank You!