



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

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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

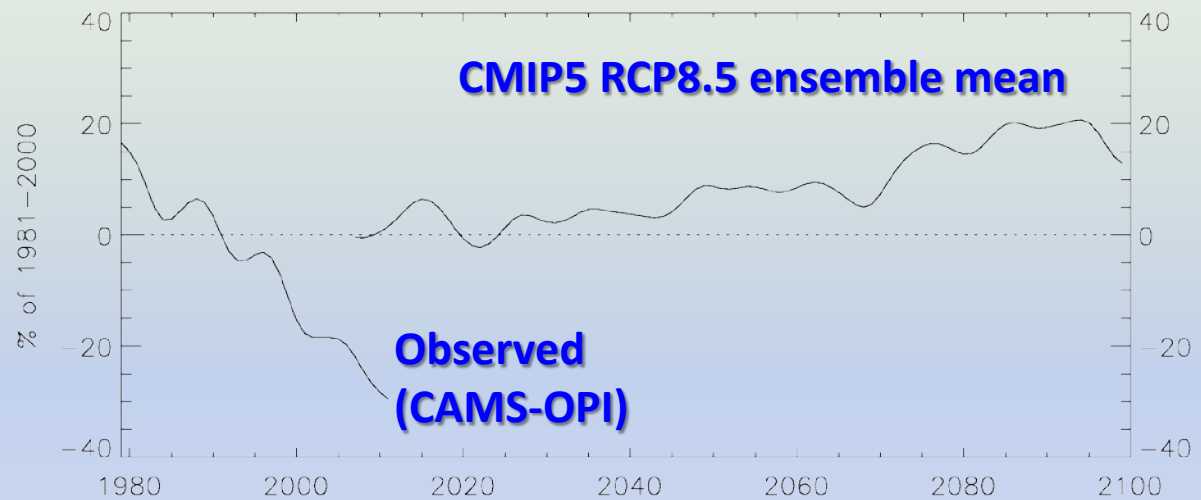
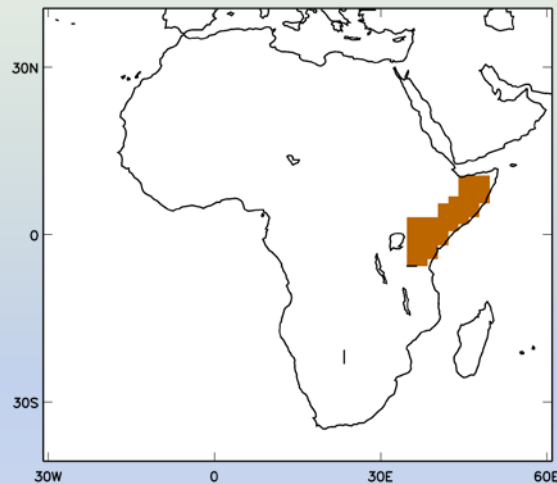
Lake Victoria Basin



- 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

East African Climate Change Paradox

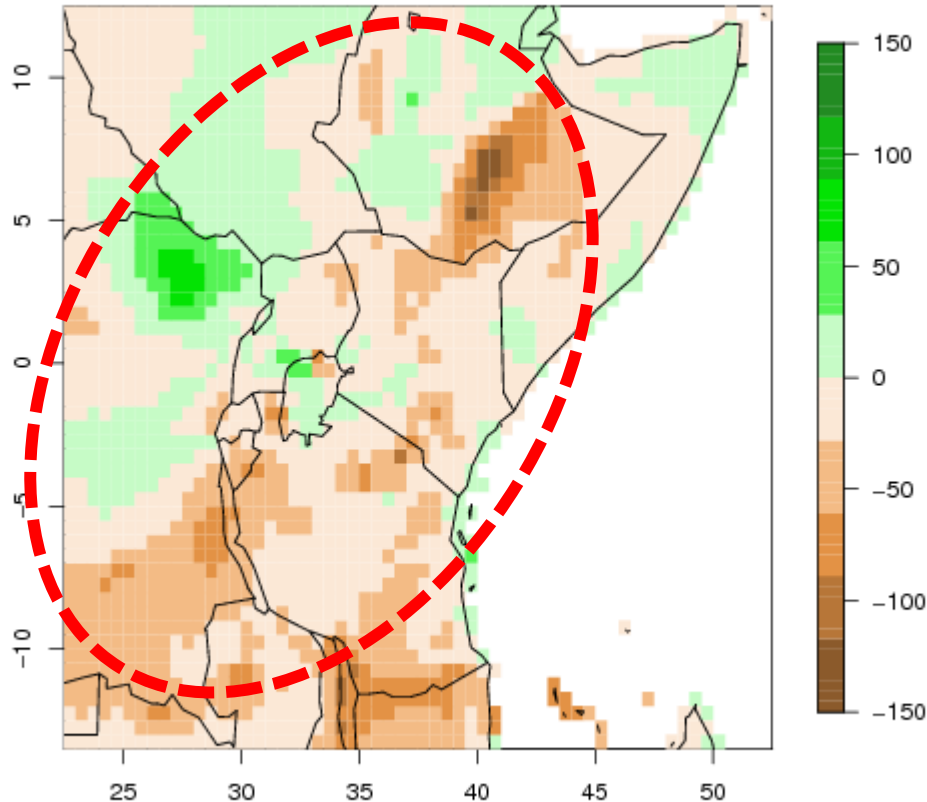
Low-pass filtered rainfall (>10yr), MAM average over Greater Horn of Africa



*(David Rowell,
UKMO, 2013)*

- 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

East African Drought (CRU Rainfall)



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

Composite of Rainfall for dry (1985-2000) minus wet (1970-1985)-MAM

EAC Feasibility Study Recommendation to Create HyVic International Research Project under the Auspices of GEWEX/WCRP

High Level Science Questions

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,⁷ construction and disaster risk management.

HyVic Project

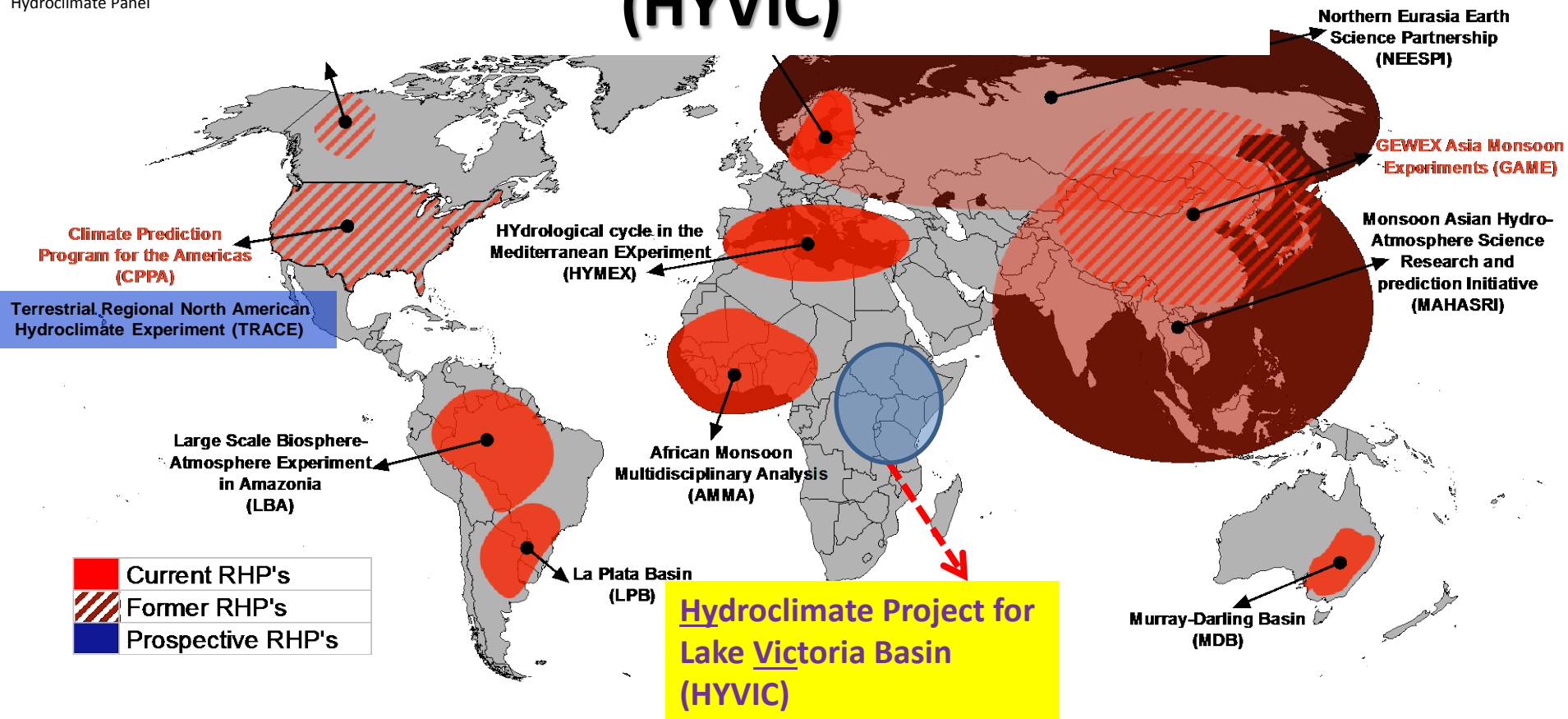


Proposed GEWEX RHP Hydroclimate Project for Lake Victoria Basin (HYVIC)



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

GHP: A GEWEX
Hydroclimate Panel



Regional water cycles

WCRP Organization

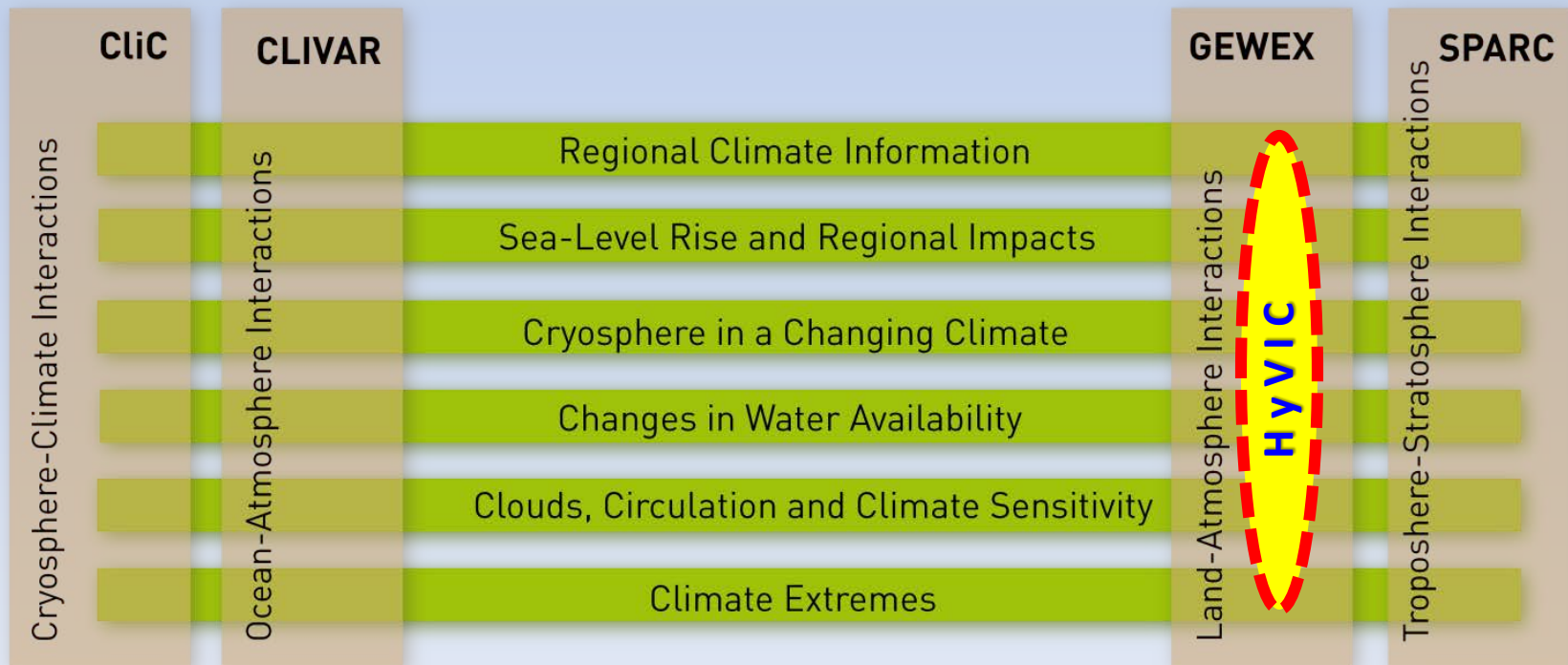
Joint Scientific Committee

Joint Planning Staff

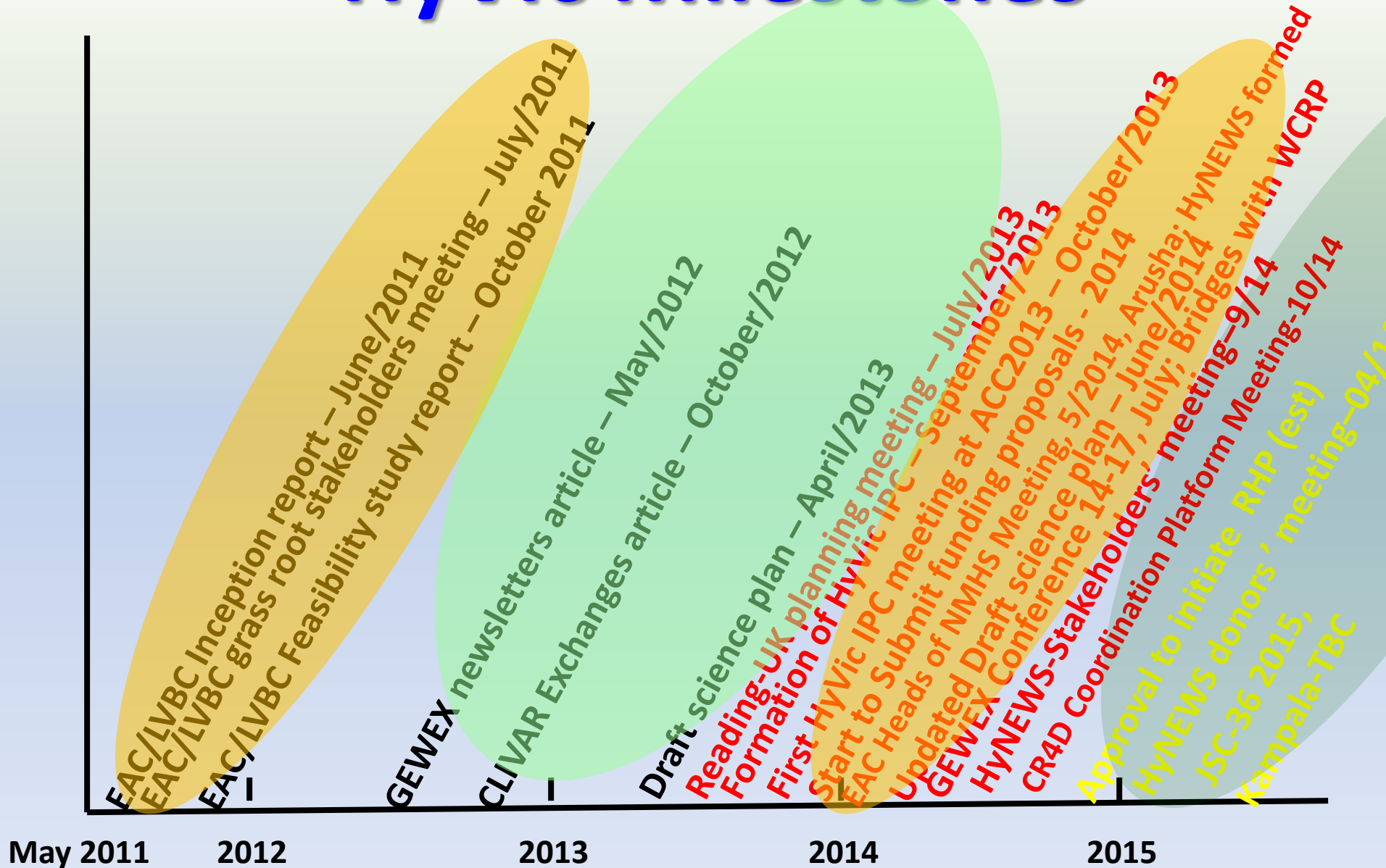
Modeling Advisory Council

Data Advisory Council

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



HyVic Milestones





HyVic Network



NCAR/UCAR



GRACE



Curtin
University
Australia

UConn



JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
Setting Trends in Higher Education, Research and Innovation

UNIVERSITY OF CONNECTICUT



UbuntuNet Alliance
for Research and Education Networking



NC STATE UNIVERSITY



ICPAC-IGAD

NSF Expedition



CEH-UK



U Liverpool



CSRP



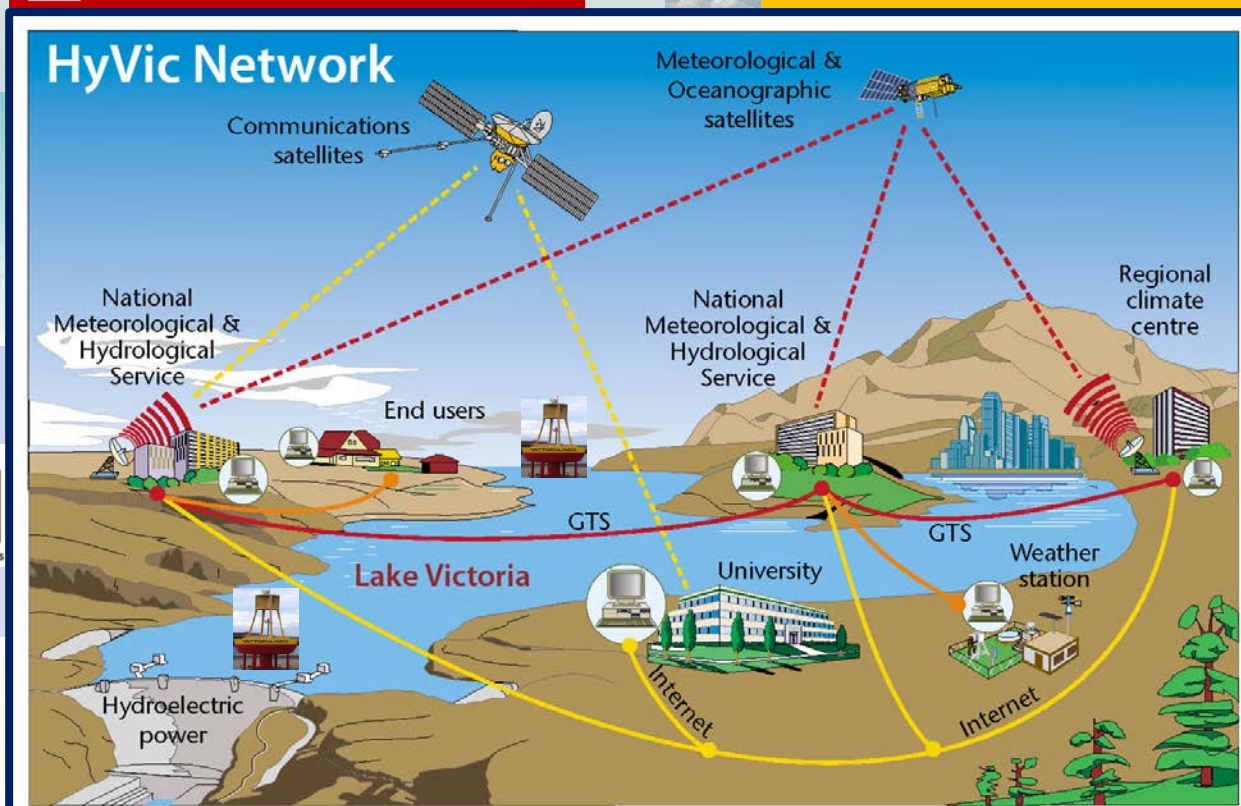
Met Office
Hadley Centre



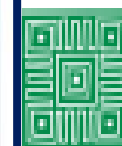
World Meteorological Organization **SWFDP**
Weather • Climate • Water



SoMAS
School of Marine and
Atmospheric Sciences



AfClix



AfClix
Africa Climate Exchange



University of
Reading

LVBC

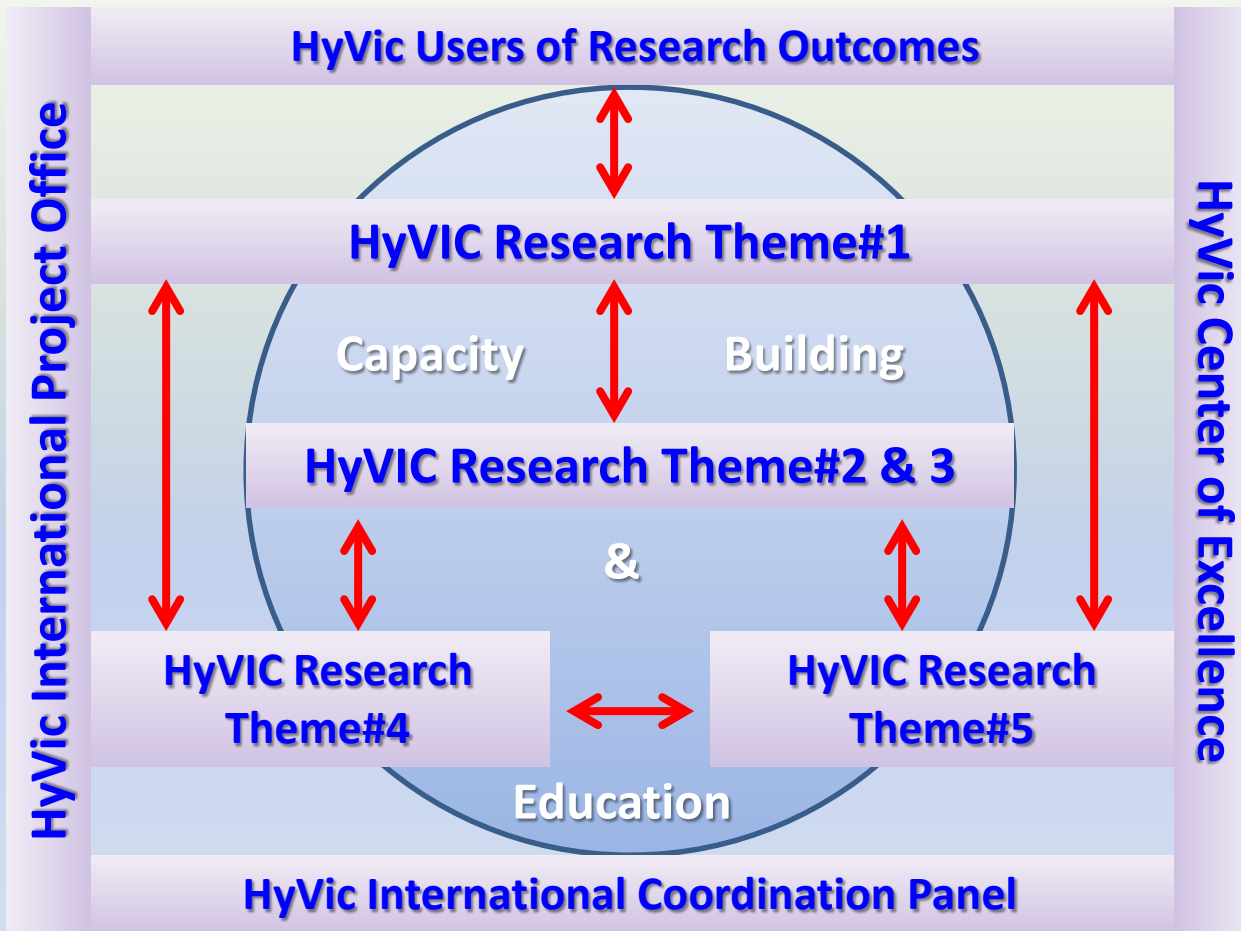


Stony Brook
University



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)

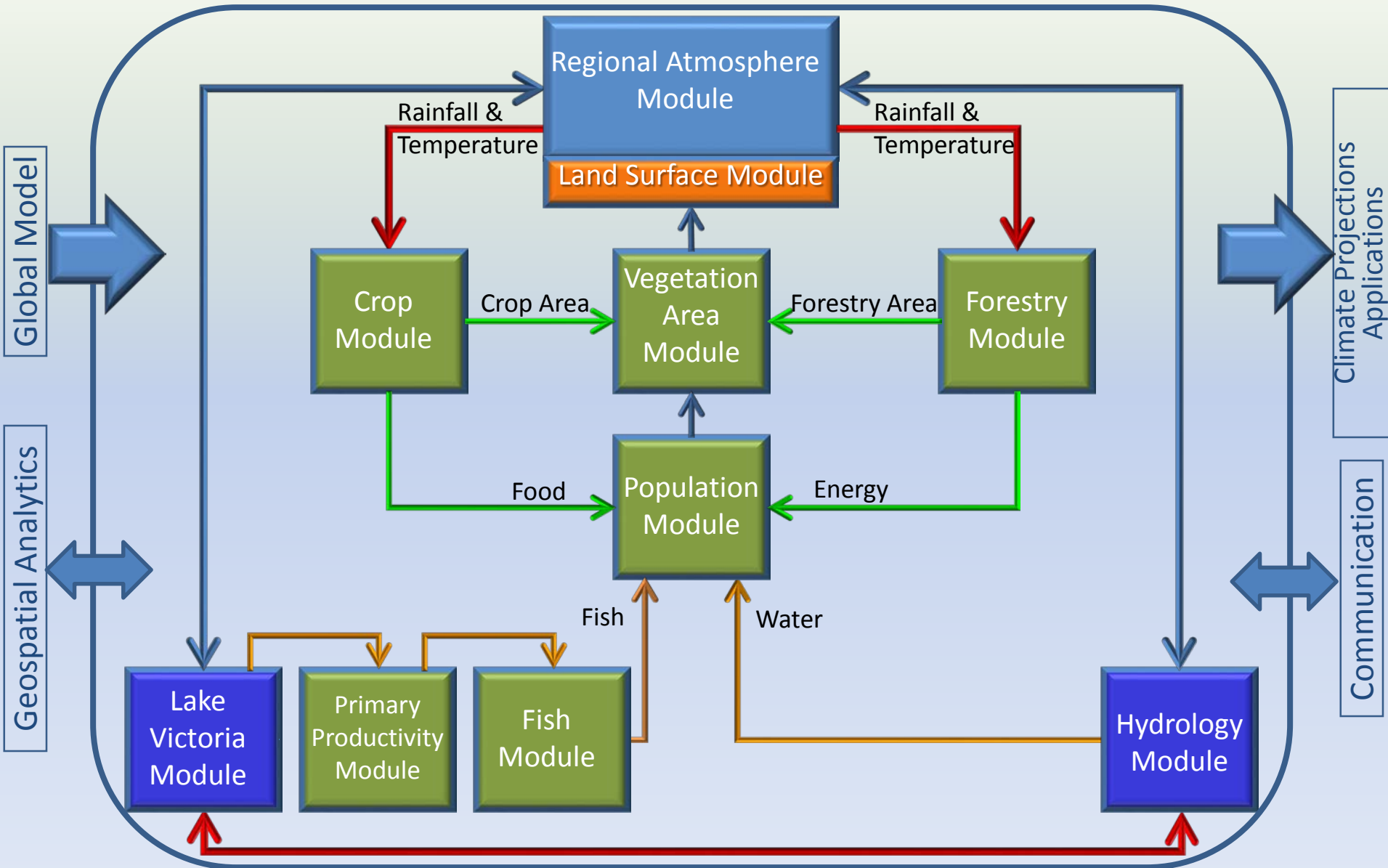
HyVIC Research Theme-3: Lake Victoria Basin Hydrologic Budget

HyVIC Research Theme-4: Climate variability and model development

HyVIC Research Theme-5: Observation of the Hydroclimatological System

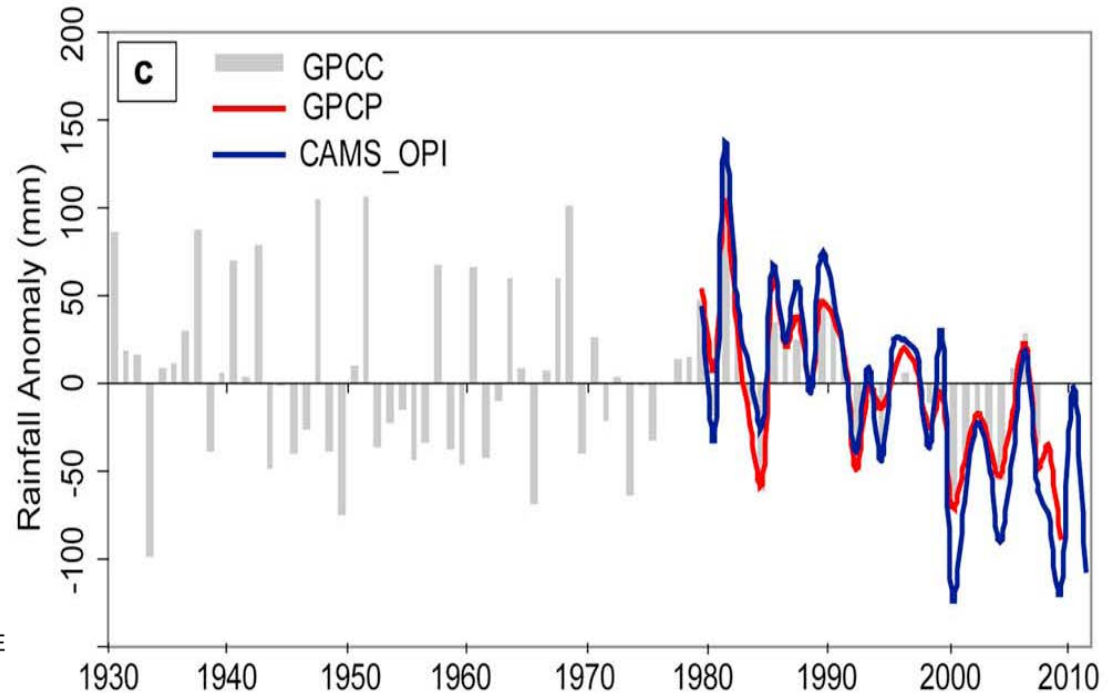
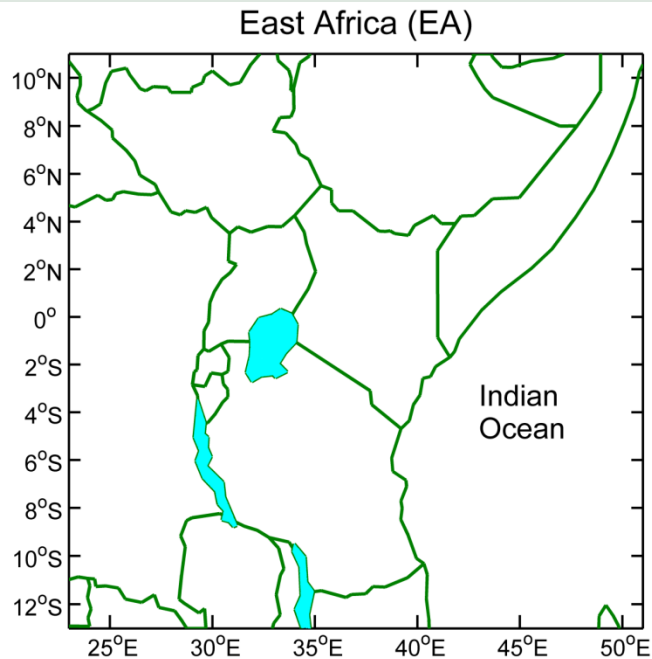
(Customized from GFCS)

HyVic Regional Earth System Model (REaSM)



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)
- **Yang et al (2014):** Modeling evidence in support of Lyon et al. (2013)
- **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

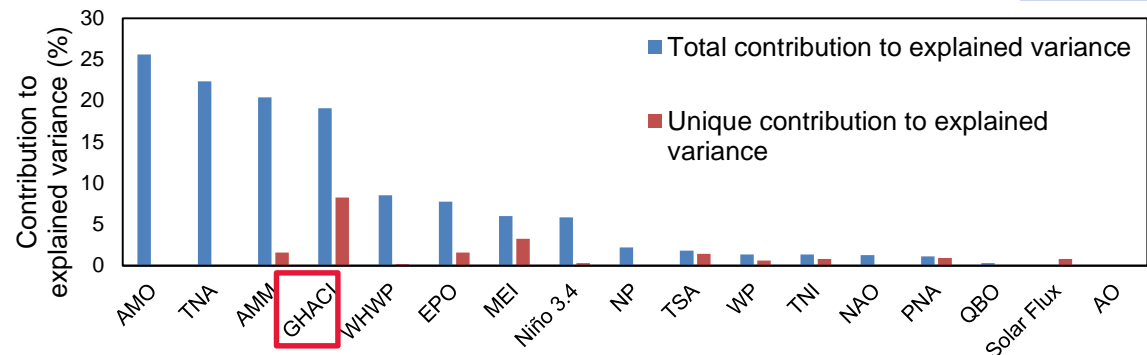
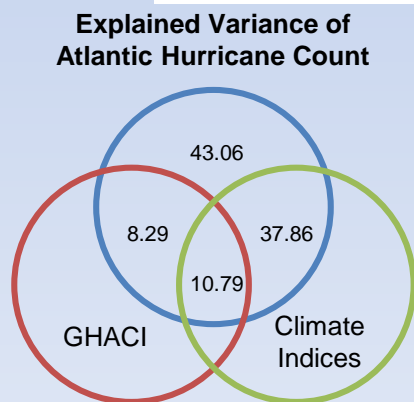
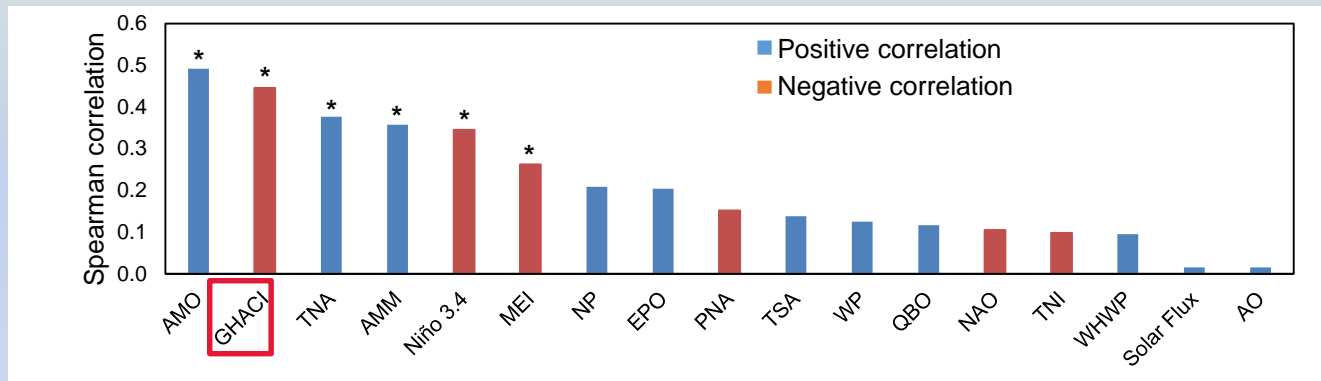
Expedition Research

Motivation from Computer Science and Climate Science Collaborative Study on Atlantic Hurricanes

GHA Hotspot Evaluation with respect to traditional climate indices

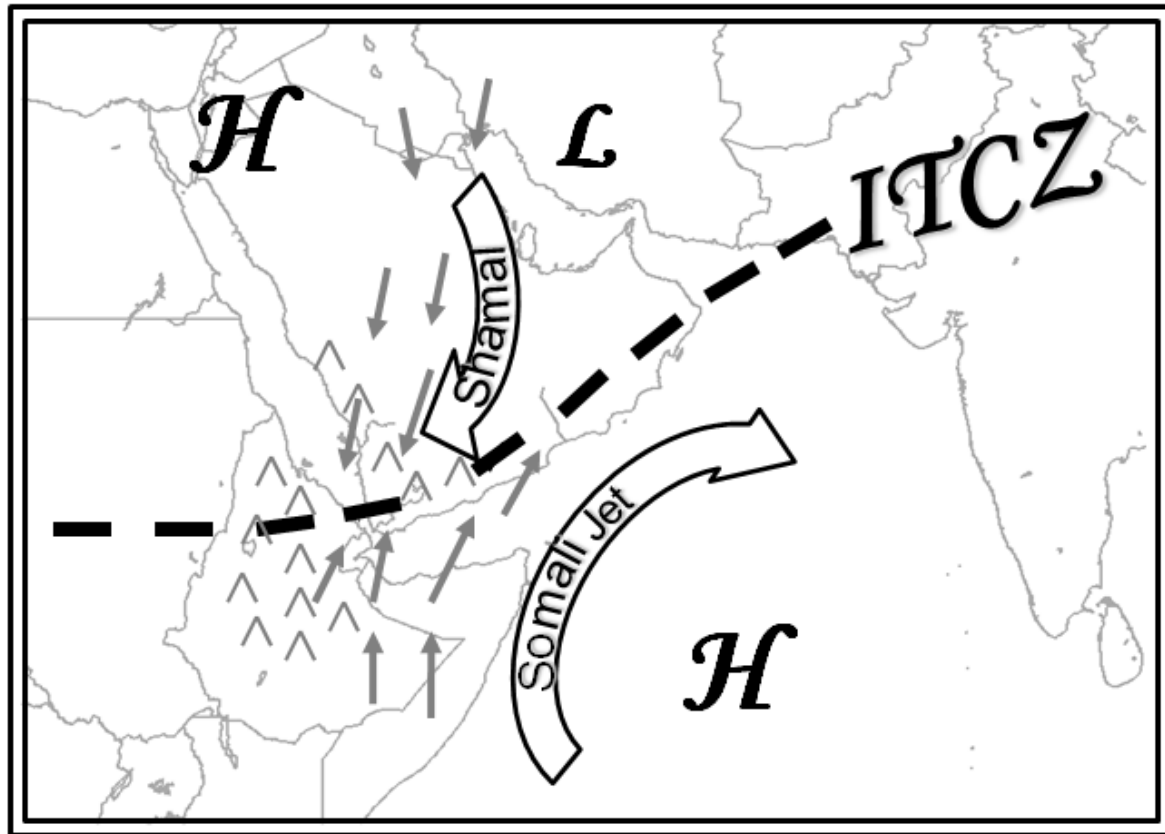


Assessed correlation and contribution to the explained variance of Atlantic hurricane count of the **GHA hotspot** with respect to traditional climate indices in June.



* indicates statistically significant correlation with $p < 0.05$

Genesis phase of AEW disturbances (Ethiopian Highlands?)

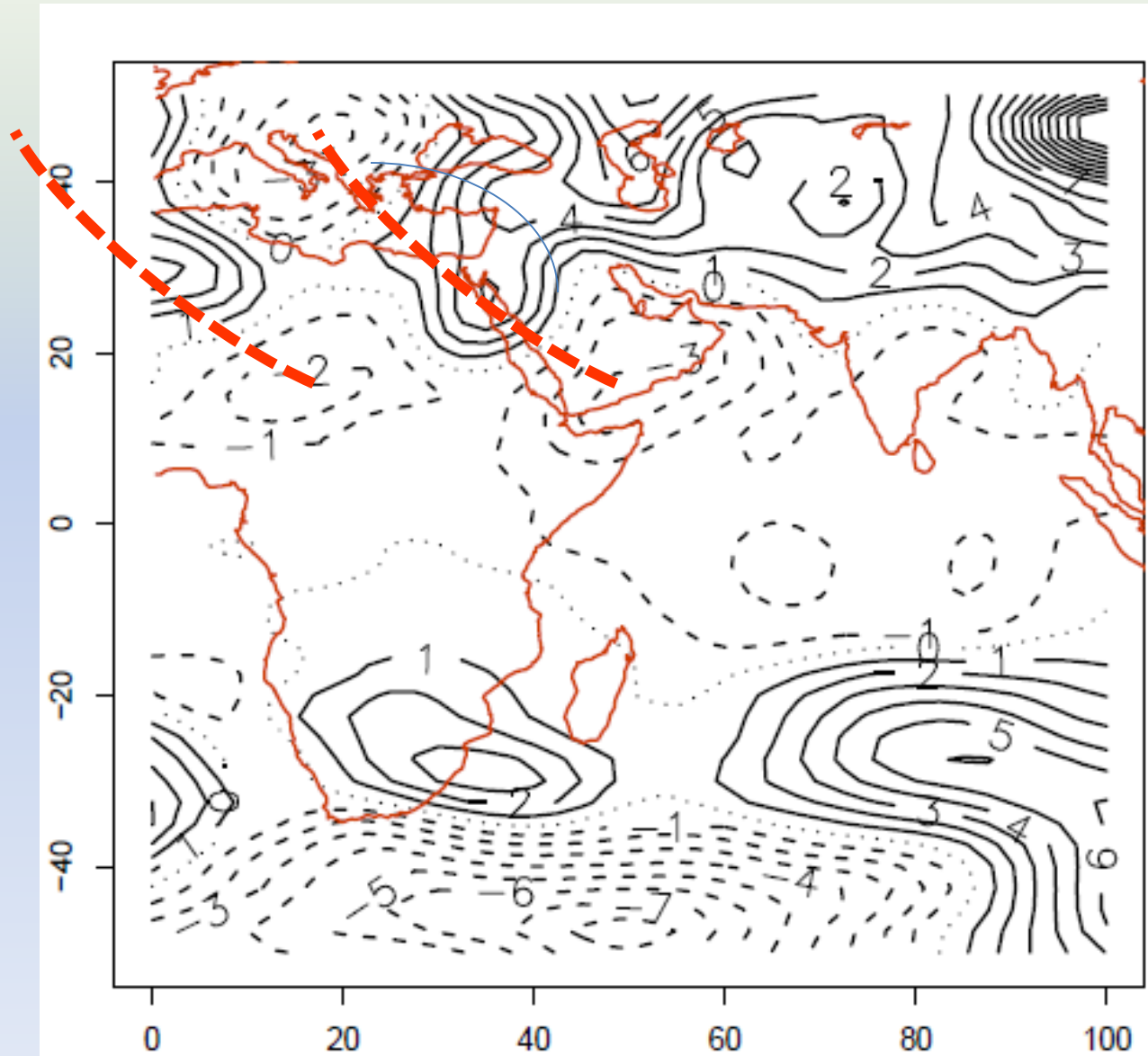


A conceptual model of generation of cyclonic vorticity perturbations and convective cloud clusters preceding the pre-Debby (2006) AEW-MCS system.

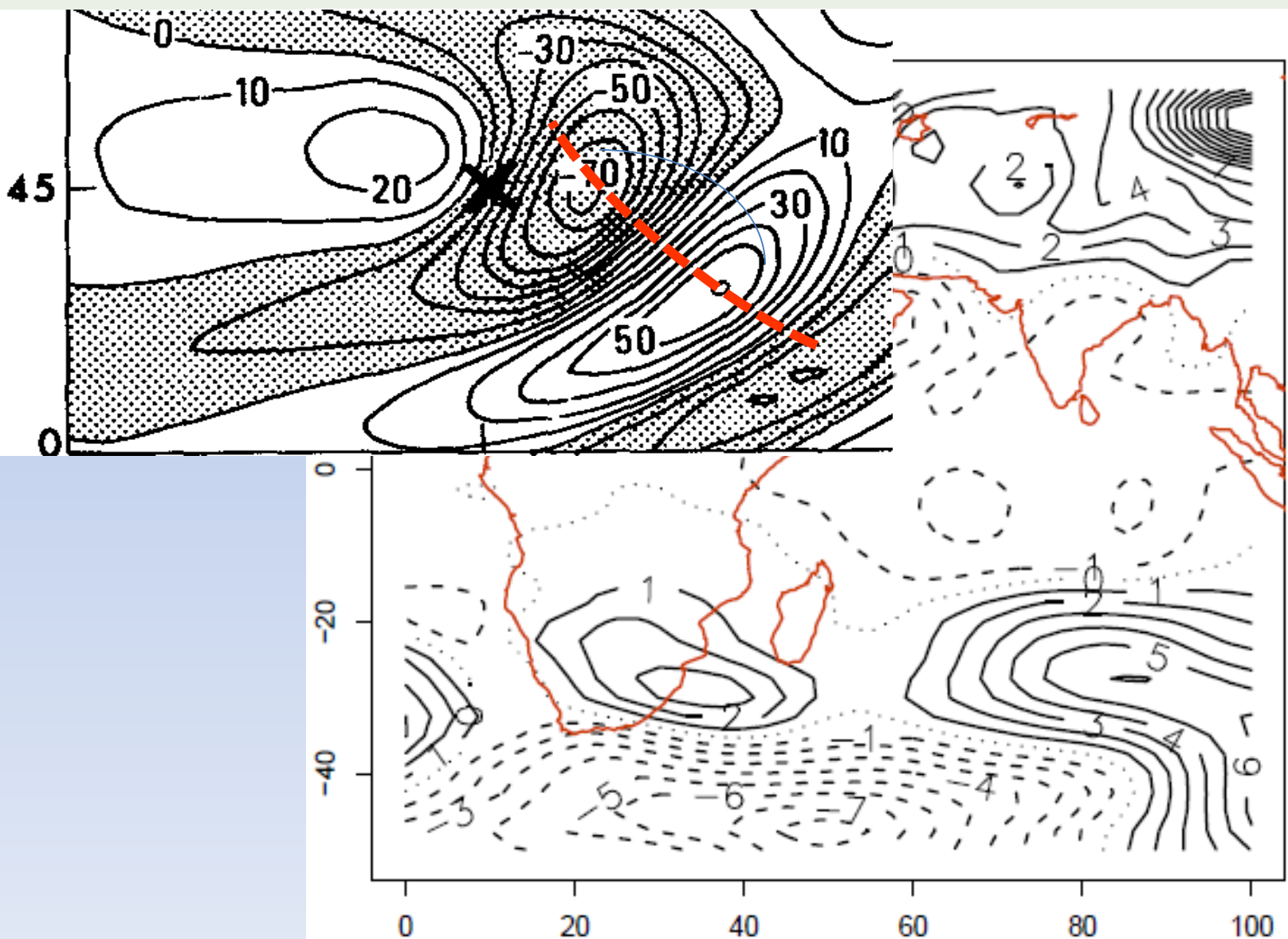
Alps Generated Stationary Rossby Wave Train in the Westerlies

Hypothesis

V-Wind anomalies at 500mb

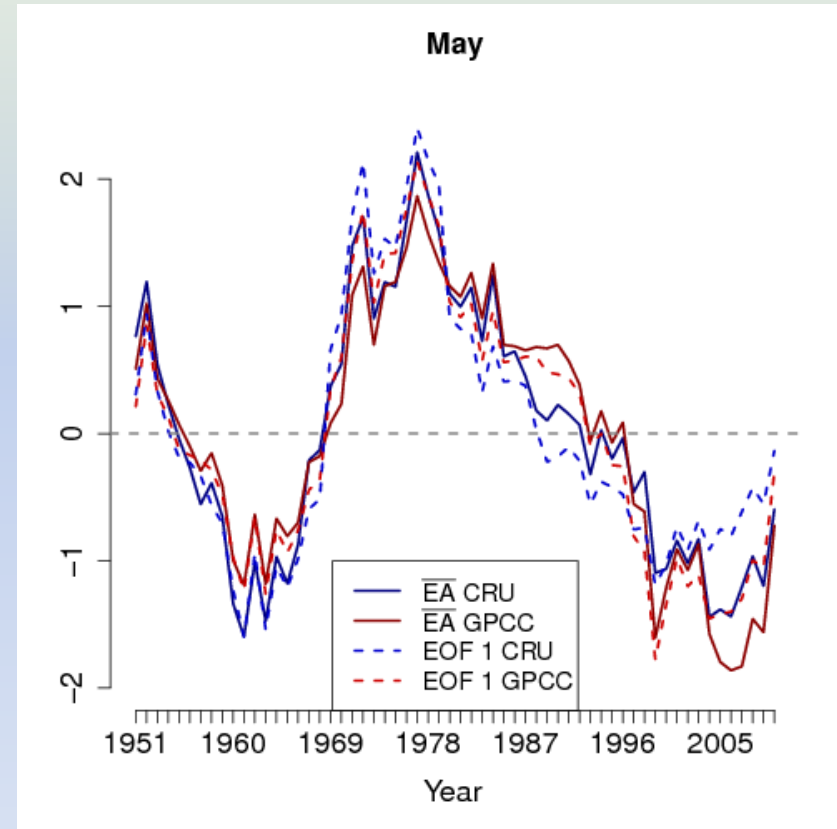
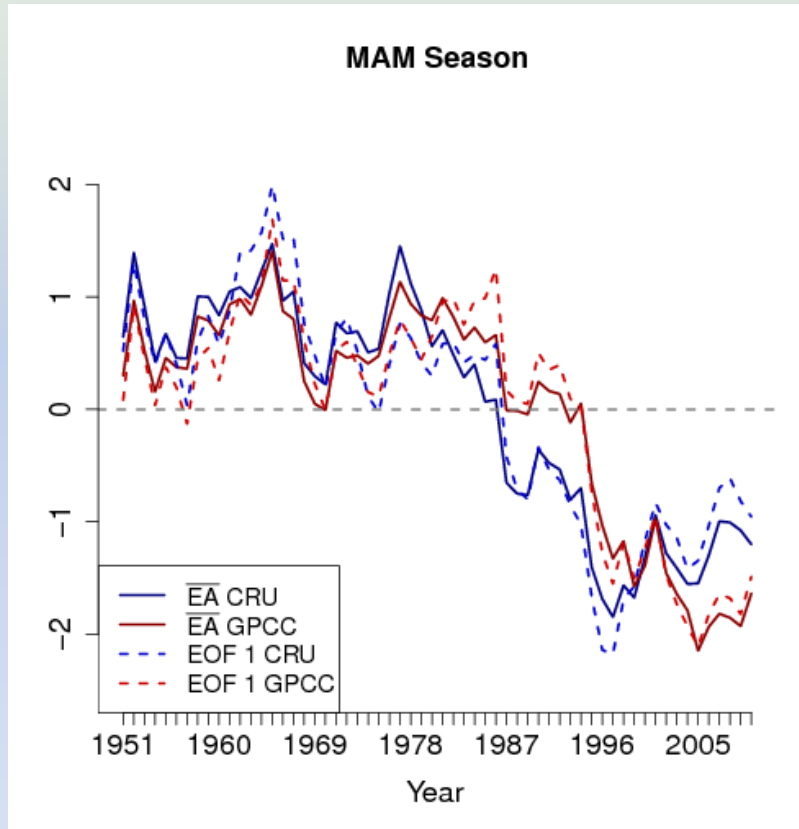


Hypothesized Geopotential Anomalies at 500mb

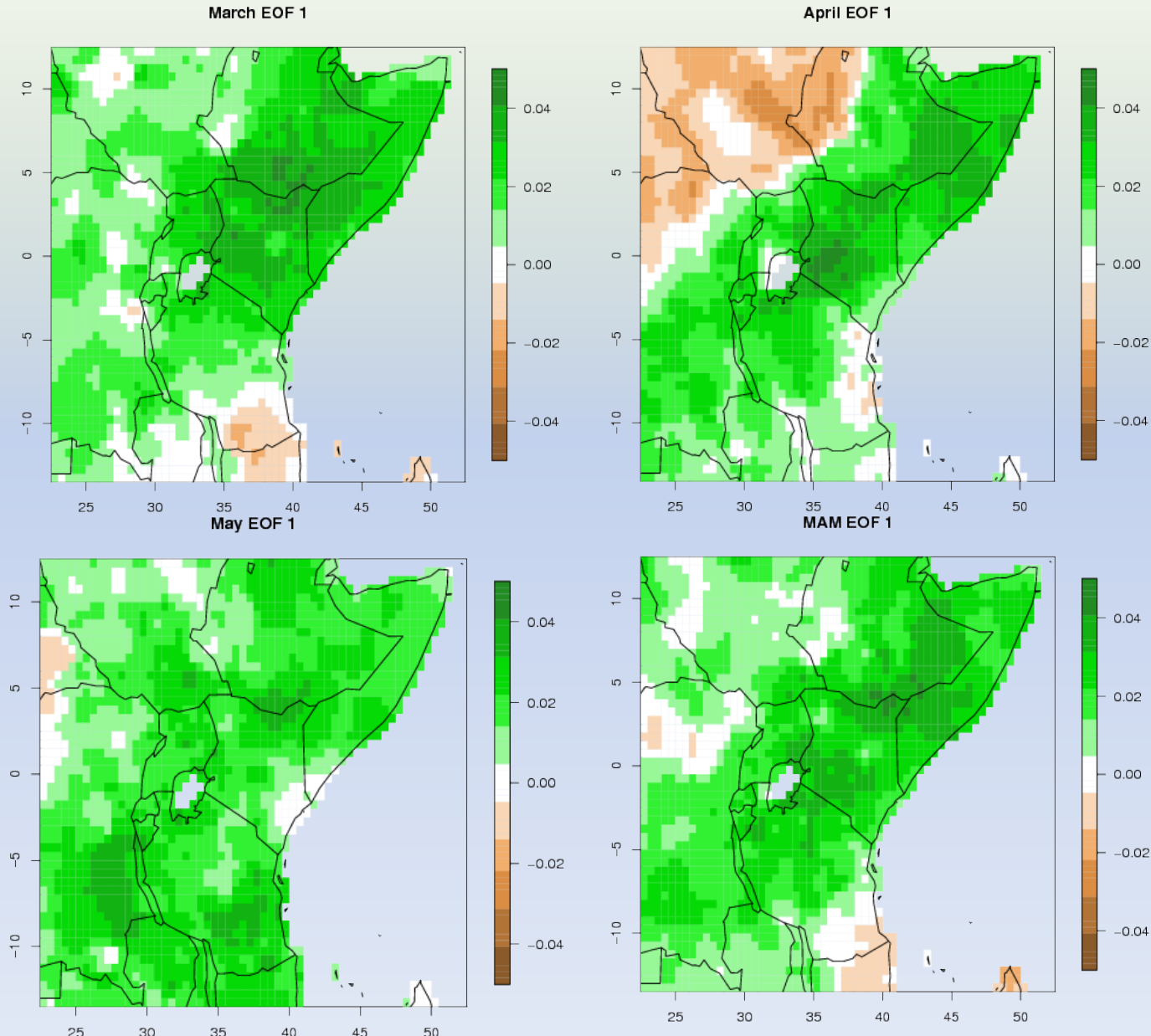


Regional Multi-Decadal Variability

MAM & May GPCC & CRU EOF1 Time series; GPCC & CRU regional Average
NOTE: (i) robustness, and (ii) LR multi-decadal decline.

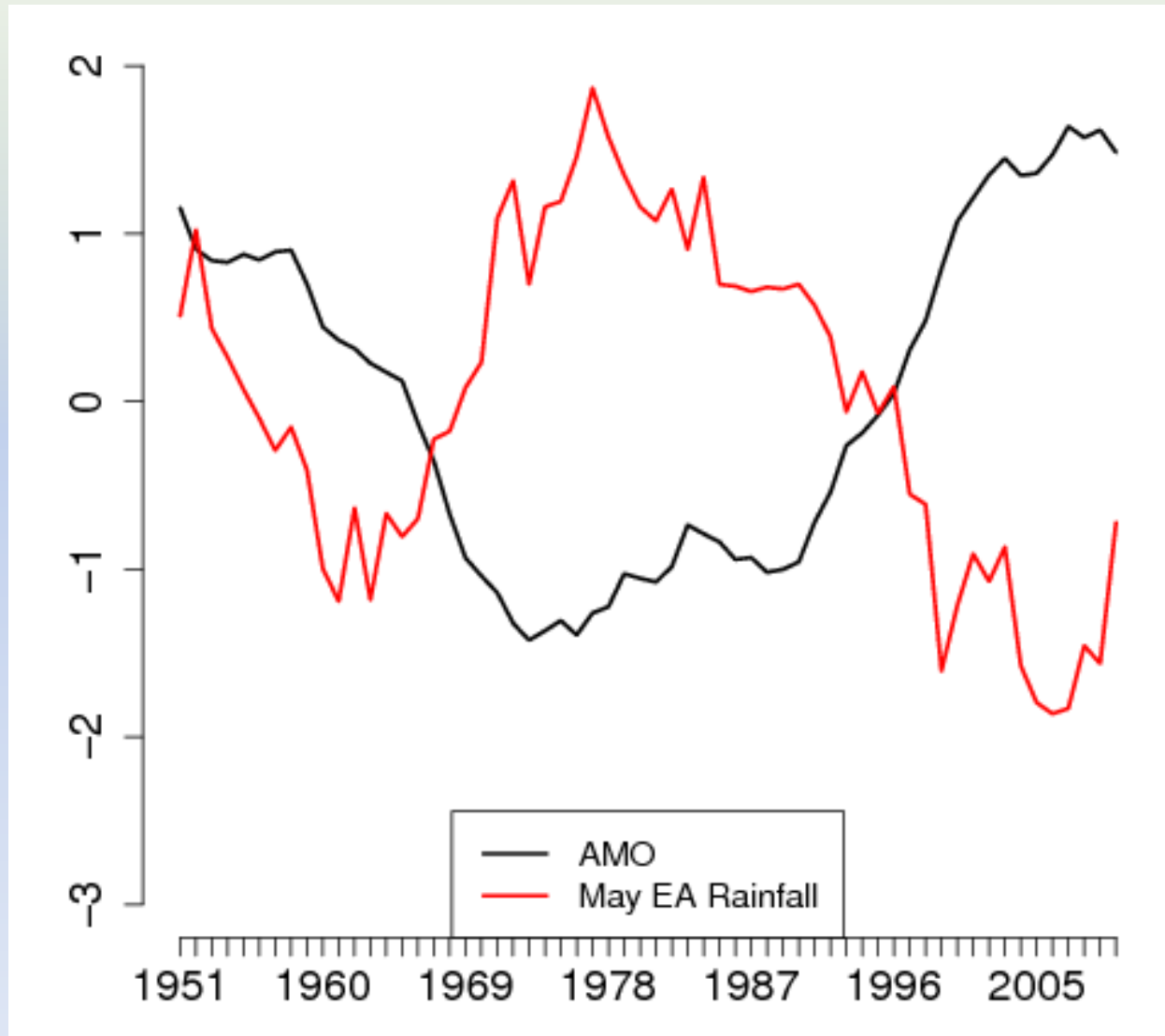


EOF1 Loading for M, A, M & MAM



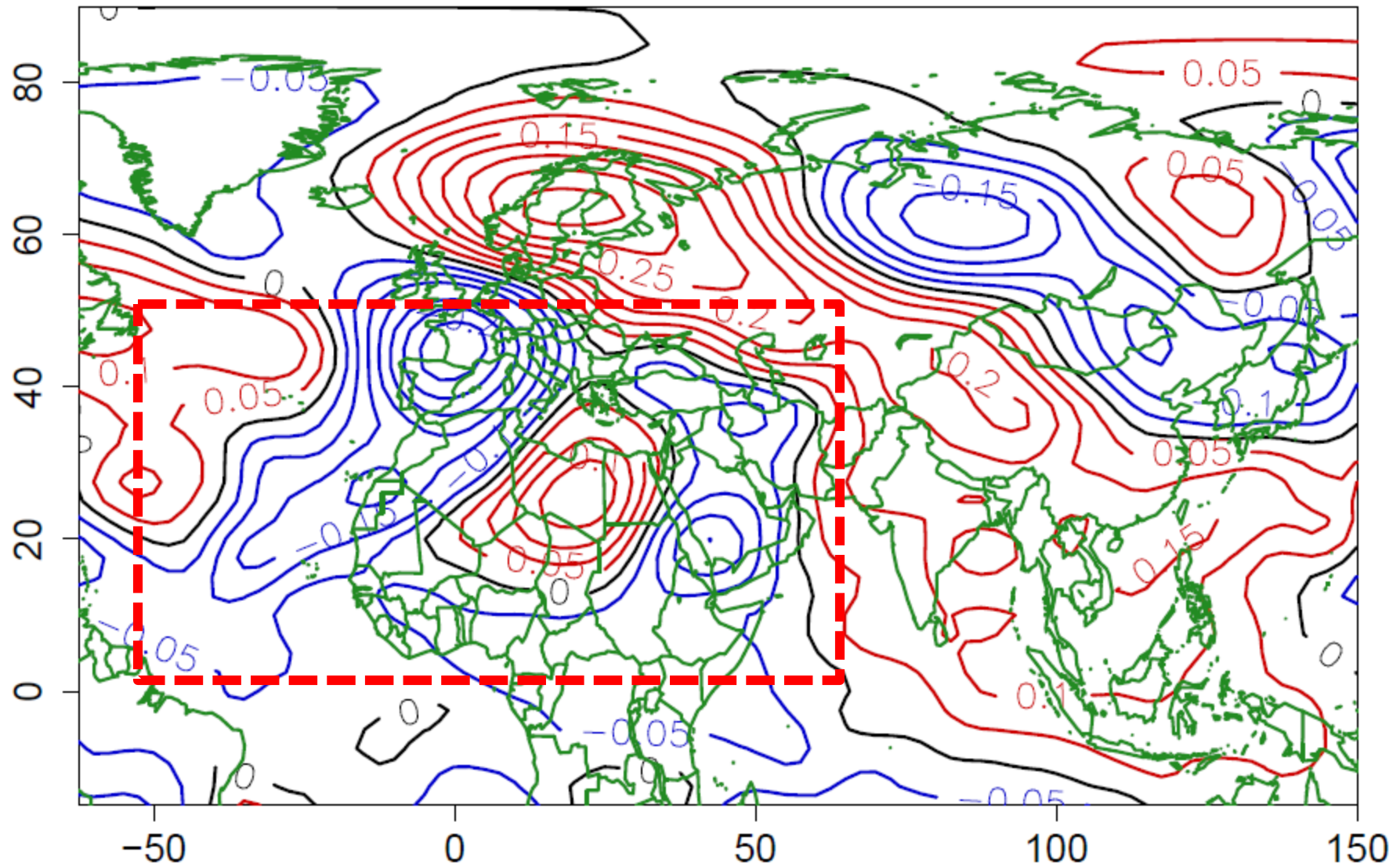
Relationship of Multi-Decadal Drought (MDD) with Global SST (GSST)

May AMO and East Africa Average Rainfall



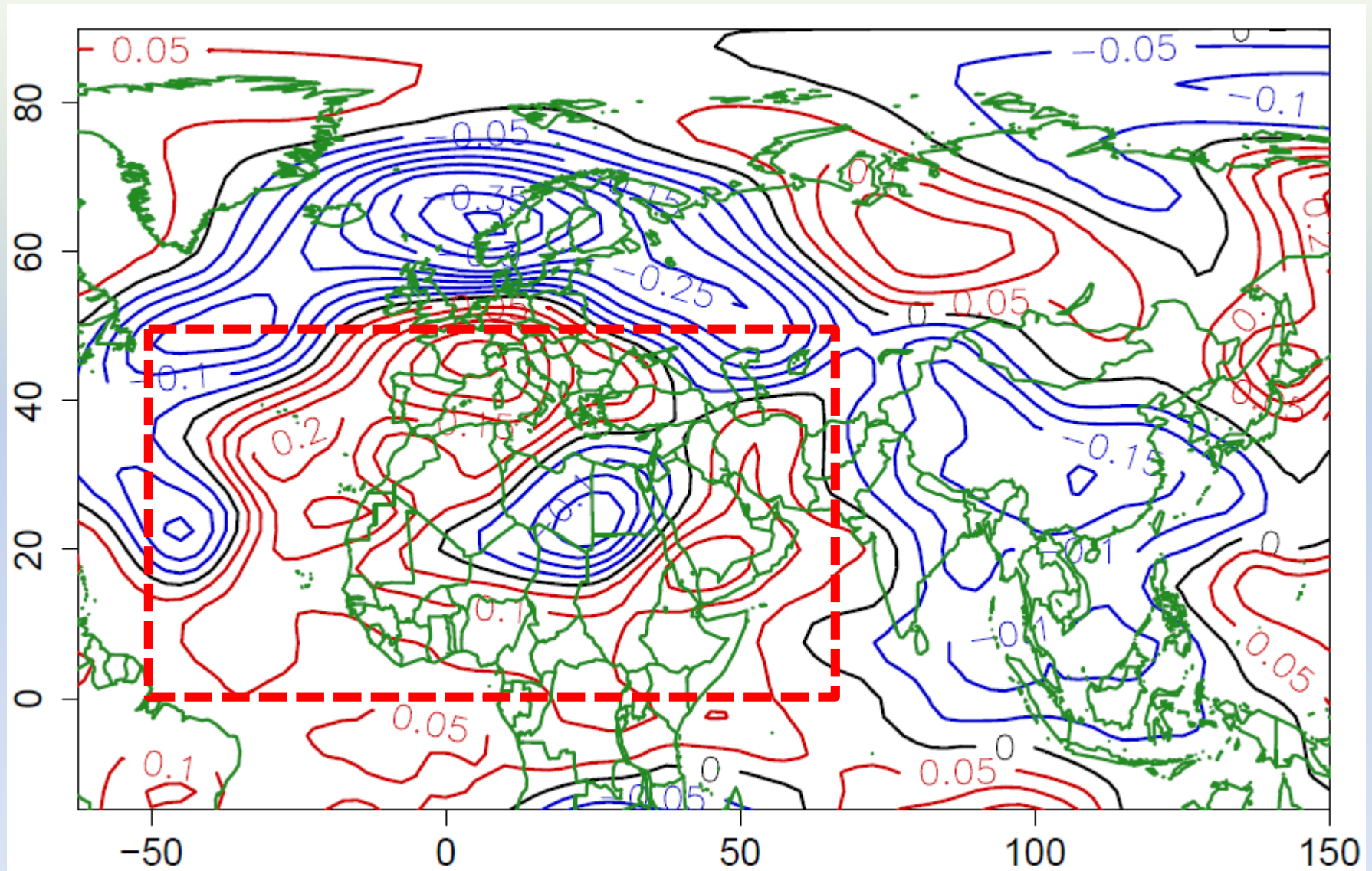
AMO-Induced Teleconnections

May EOF1 (AMO-like) geopotential at 300mb Composite (negative/positive AMO/EA rainfall)





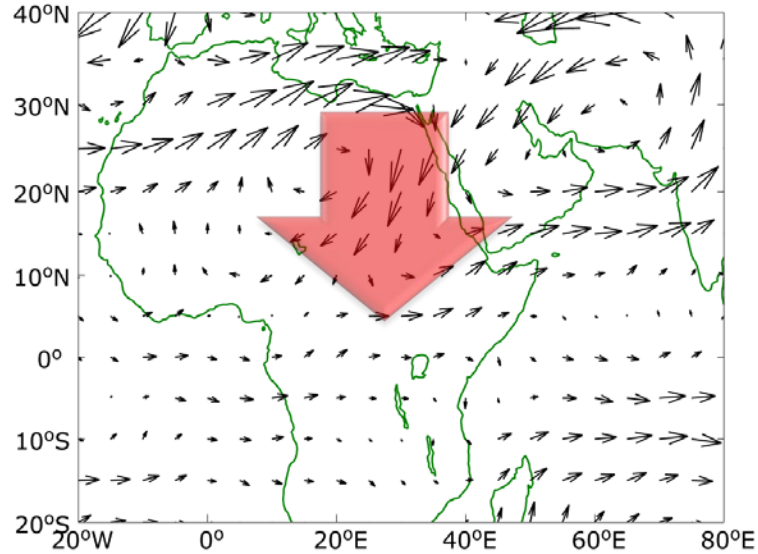
May EOF1 (AMO-like) geopotential at 300mb Composite (positive/negative AMO/EA rainfall)



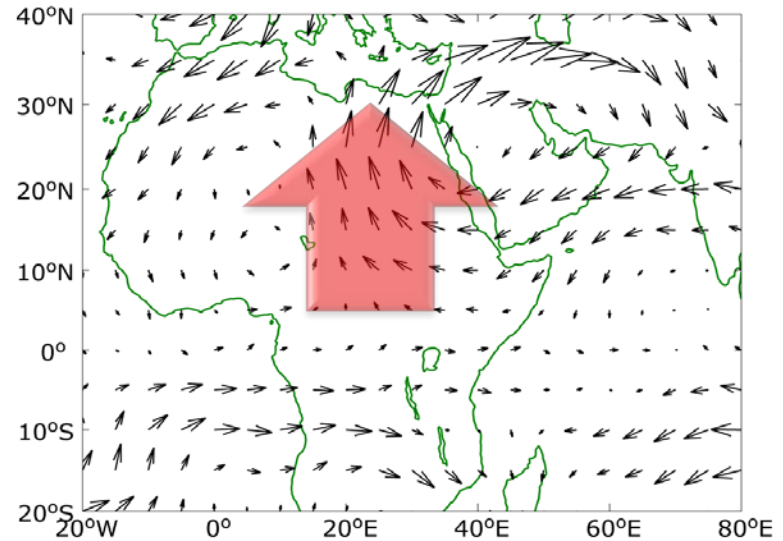


May Anomaly flow, 1951-2010 Composites

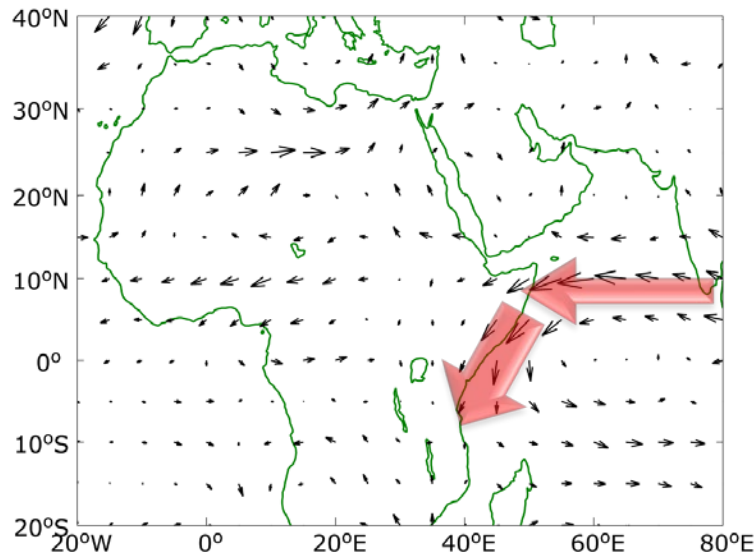
Wet Composite, 300mb



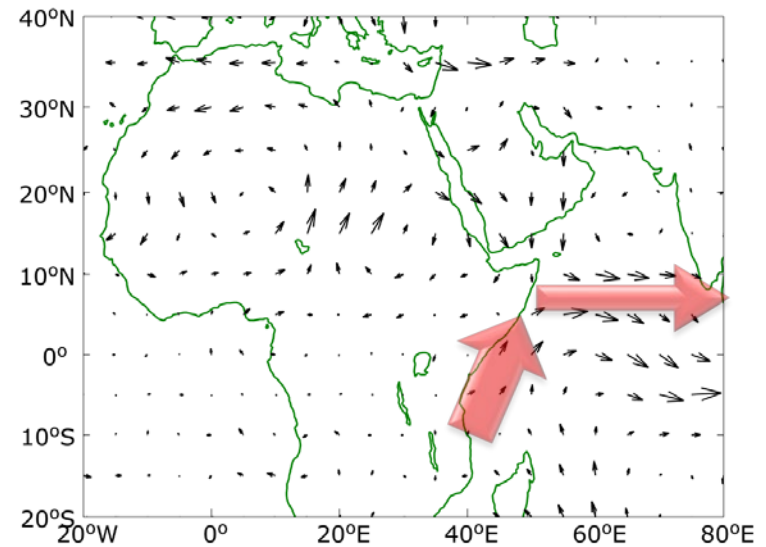
Dry Composite, 300mb



Wet Composite, 850mb



Dry Composite, 850mb



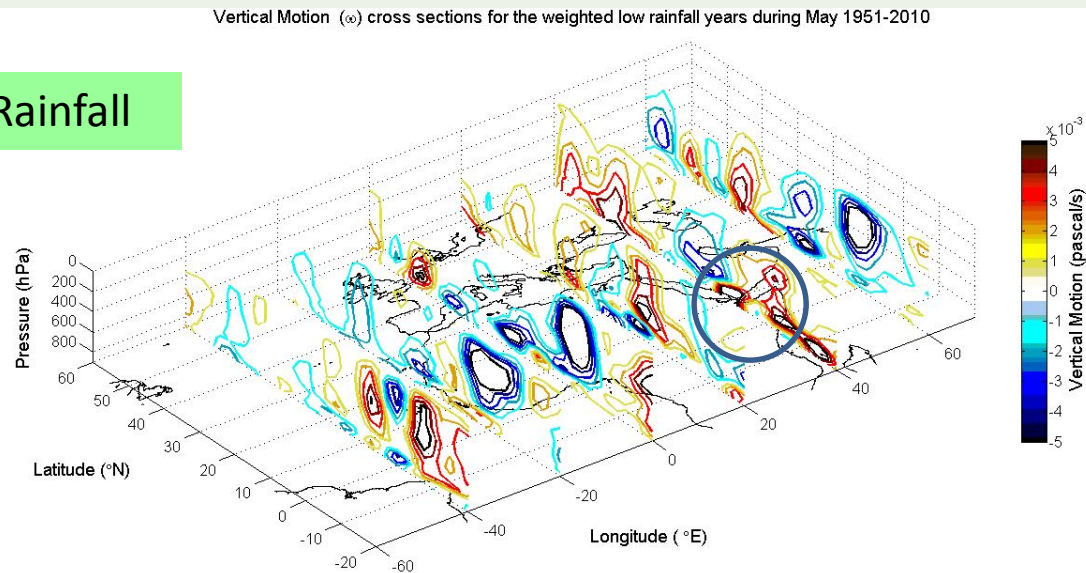
Reversal of the Cross-Equatorial Low Level Flow



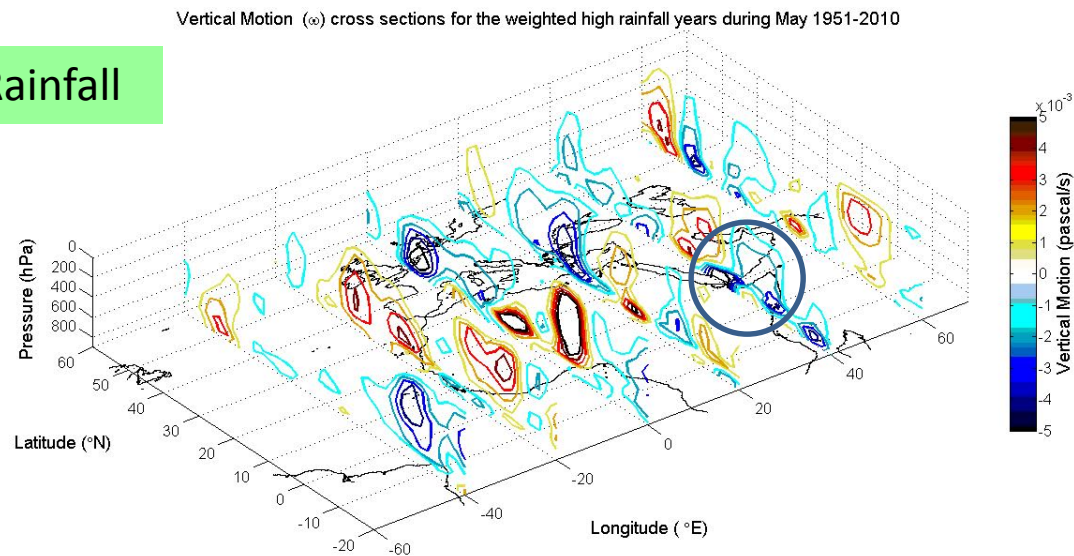
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EA domain rainfall EOF1 (AMO-like mode) vertical cross-sections composites for the vertical motion

Low Rainfall



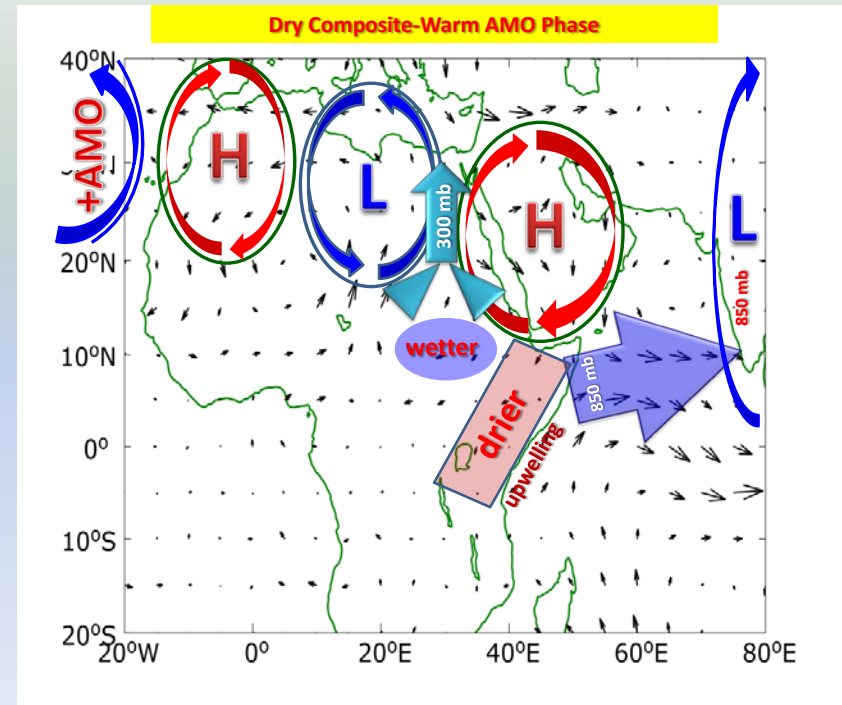
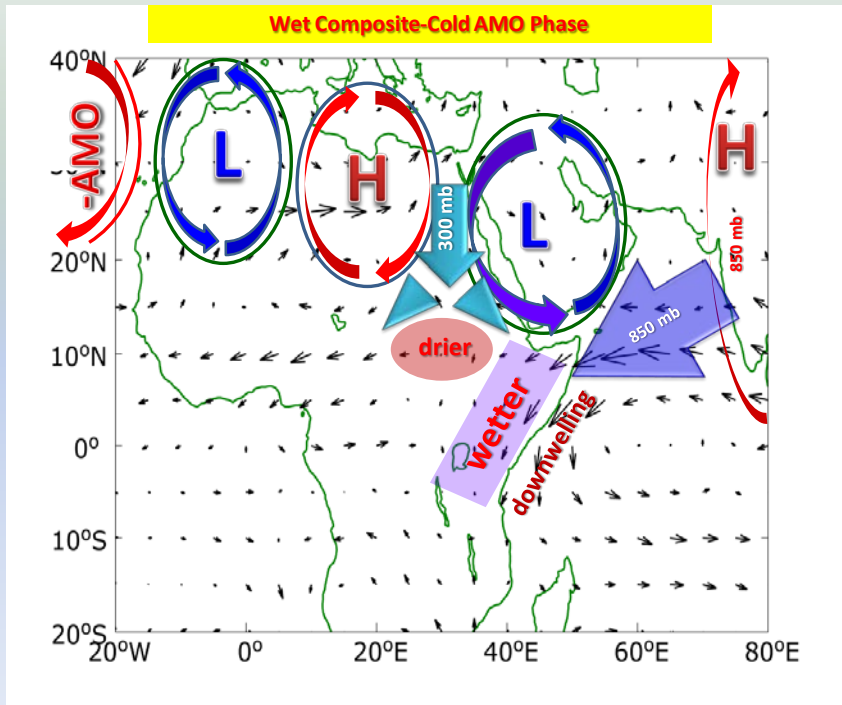
High Rainfall





Integrated Conceptual Model of AMO Teleconnection Mechanisms

Combined Contributions



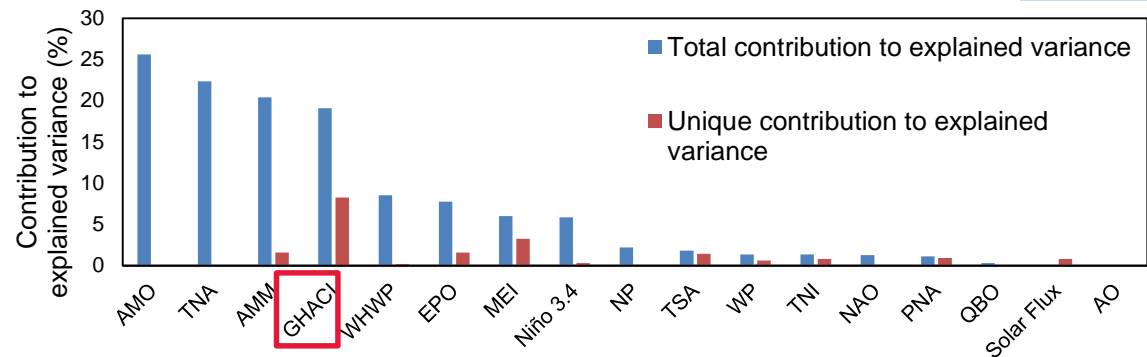
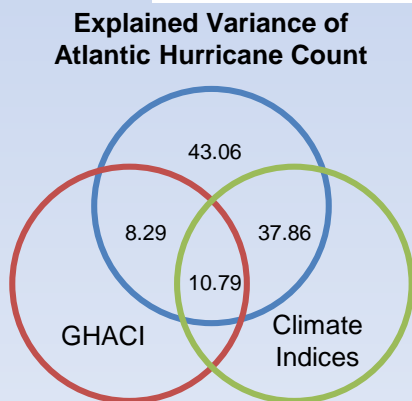
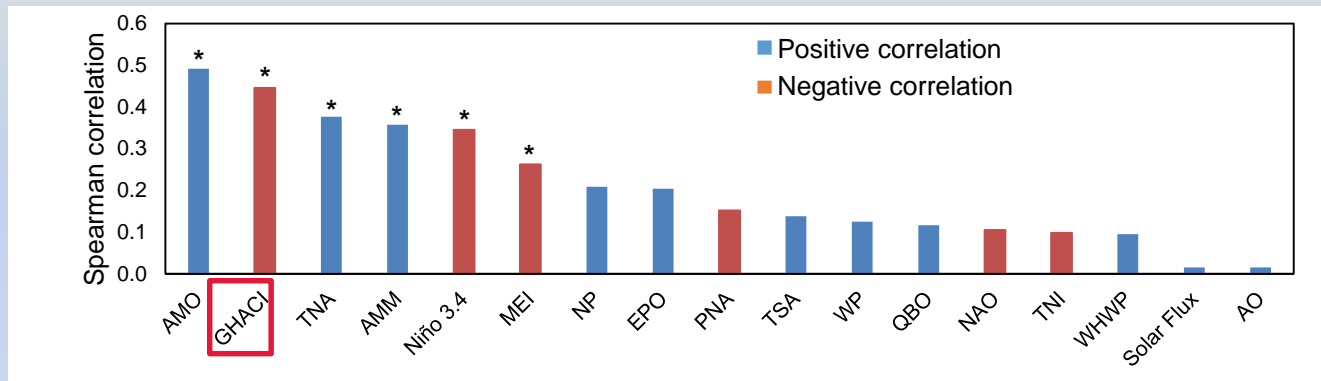
Conclusions

- 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.



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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!