Application of Climate Model and Remote Sensed Data to Understand Lake Victoria Hydrologic Variations

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Climate Change and Lake Victoria Water

- Developing African nations are identified as most vulnerable to climate change.

- Water is and will continue to be a limiting factor for development.

- Lake Victoria water levels are at the lowest level in 80 years. This is partly due to natural variability, but is also due to climate change and water diversions.

- The Owen Falls Extension, Kiira Dam, built in 2000 resulted in disparities from the Agreed Water Curve release rates (Lake Victoria Basin Comm. 2006).

- Severe lake level falls during 2004-2005 were calculted to be 45% due to drought and 55% due to over-releases from the dams.

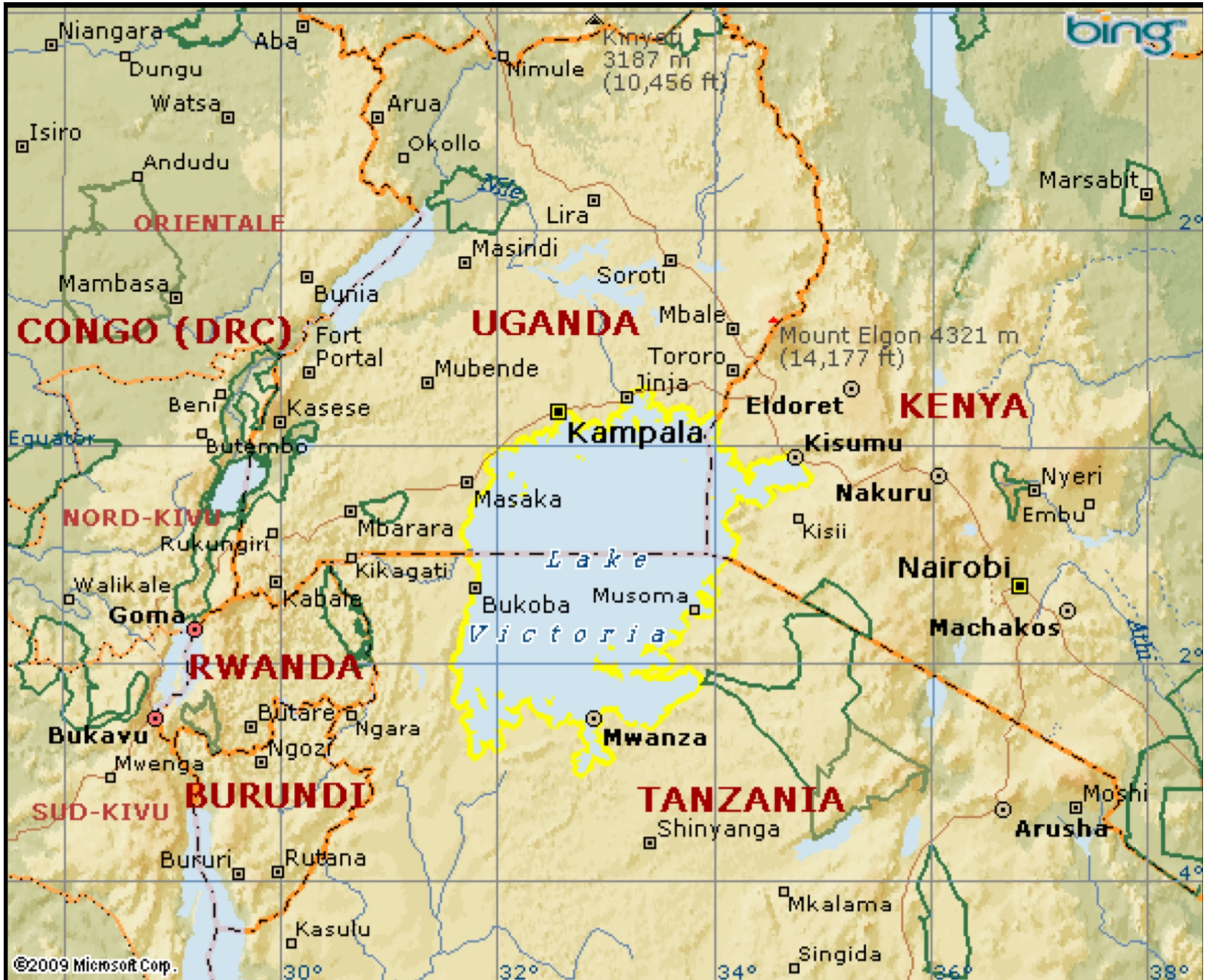
Climate Vulnerability Assessment

Vulnerability = Risk - Adaptation

Risk = Hazard (Climate Change&Extreme Weather) X Likelihood

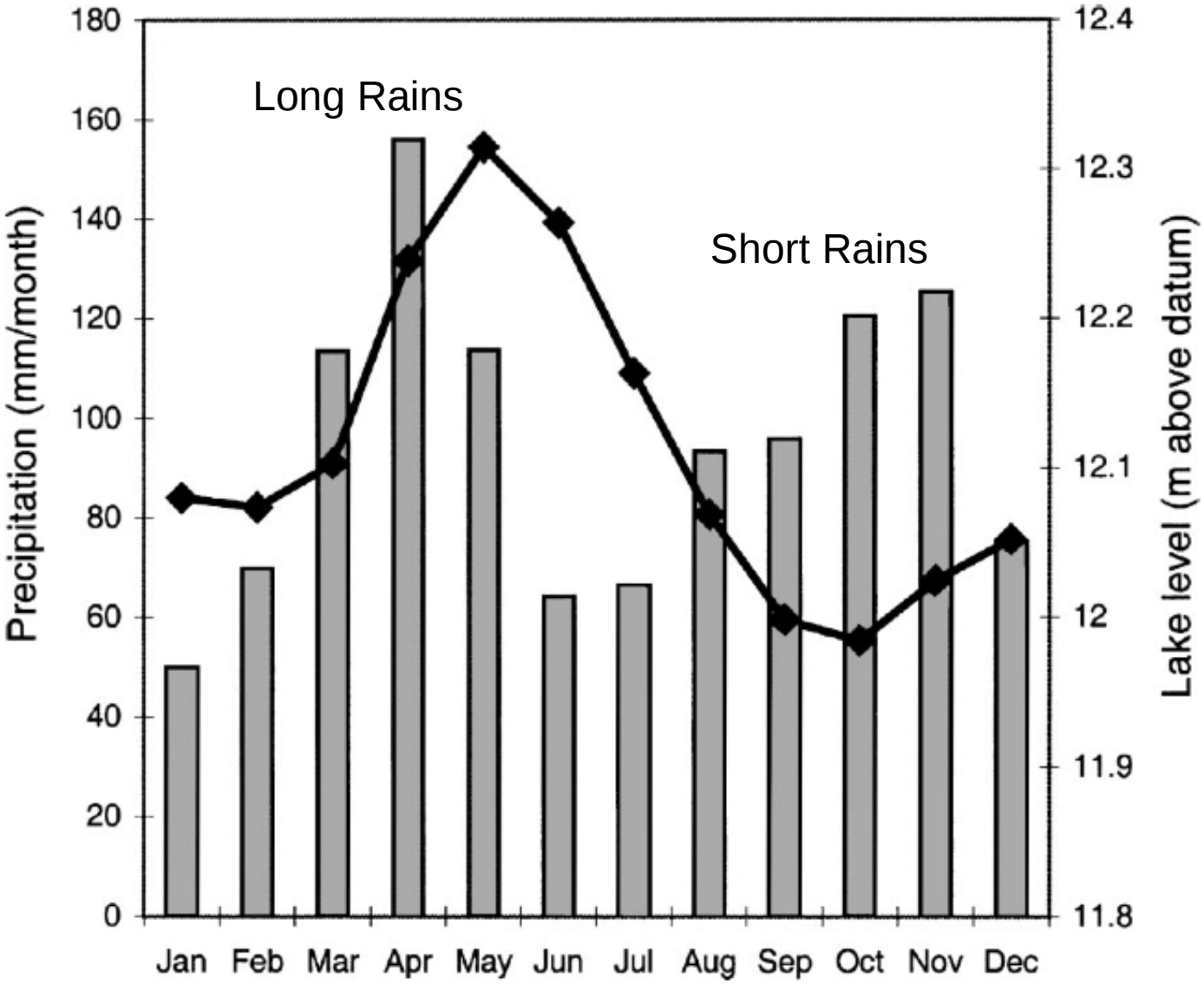
Decreasing water utility vulnerability due to climate change requires:

1. Quantifying the risk of projected climate change impacts
2. Planning adaptation strategies that increase resilience

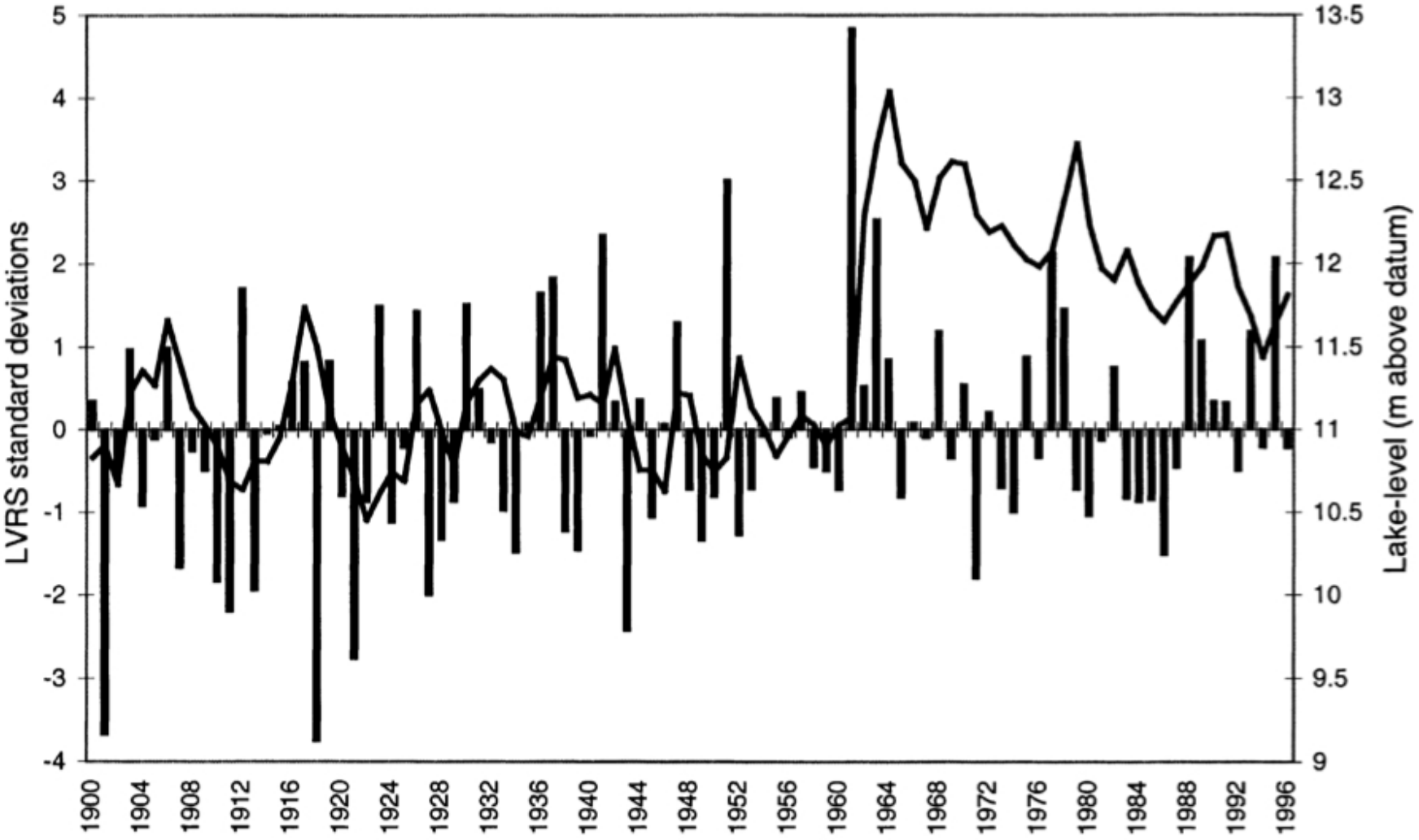

bing
Niangara
Aba
Dungu
Watsa
Isiro
Andudu
Nimule
Kinyeti
3187 m
(10,456 ft)
Arua
Okollo
Nile
Lira
Marsabit
ORIENTALE
Masindi
Soroti
Mambasa
Bunia
CONGO (DRC)
Fort
Portal
UGANDA
Mbale
Mount Elgon 4321 m
(14,177 ft)
Tororo
Mubende
Jinja
Eldoret
KENYA
Beni
Kasese
Equator
Butembo
Kampala
Kisumu
Nyeri
Nakuru
Masaka
NORD-KIVU
Mbarara
Embu
Kisii
Rukungiri
Lake
Nairobi
Walikale
Kikagati
Kabale
Bukoba
Musoma
Goma
Machakos
Victoria
RWANDA
Butare
Ngara
Bukavu
Ngozi
Mwanza
Mwenga
BURUNDI
TANZANIA
Moshi
SUD-KIVU
Shinyanga
Arusha
Bururi
Rutana
Mkalama
Kasulu
Singida
©2009 Microsoft Corp.
30°
32°
34°
36°
38°
2°
4°

Dam Over-Releases:
55% of Lake Victoria Water Levels

Lake Victoria Precipitation (bars) and Water Level (diamonds)



Lake Victoria Rain Timeseries (bars) and Water Level (line)



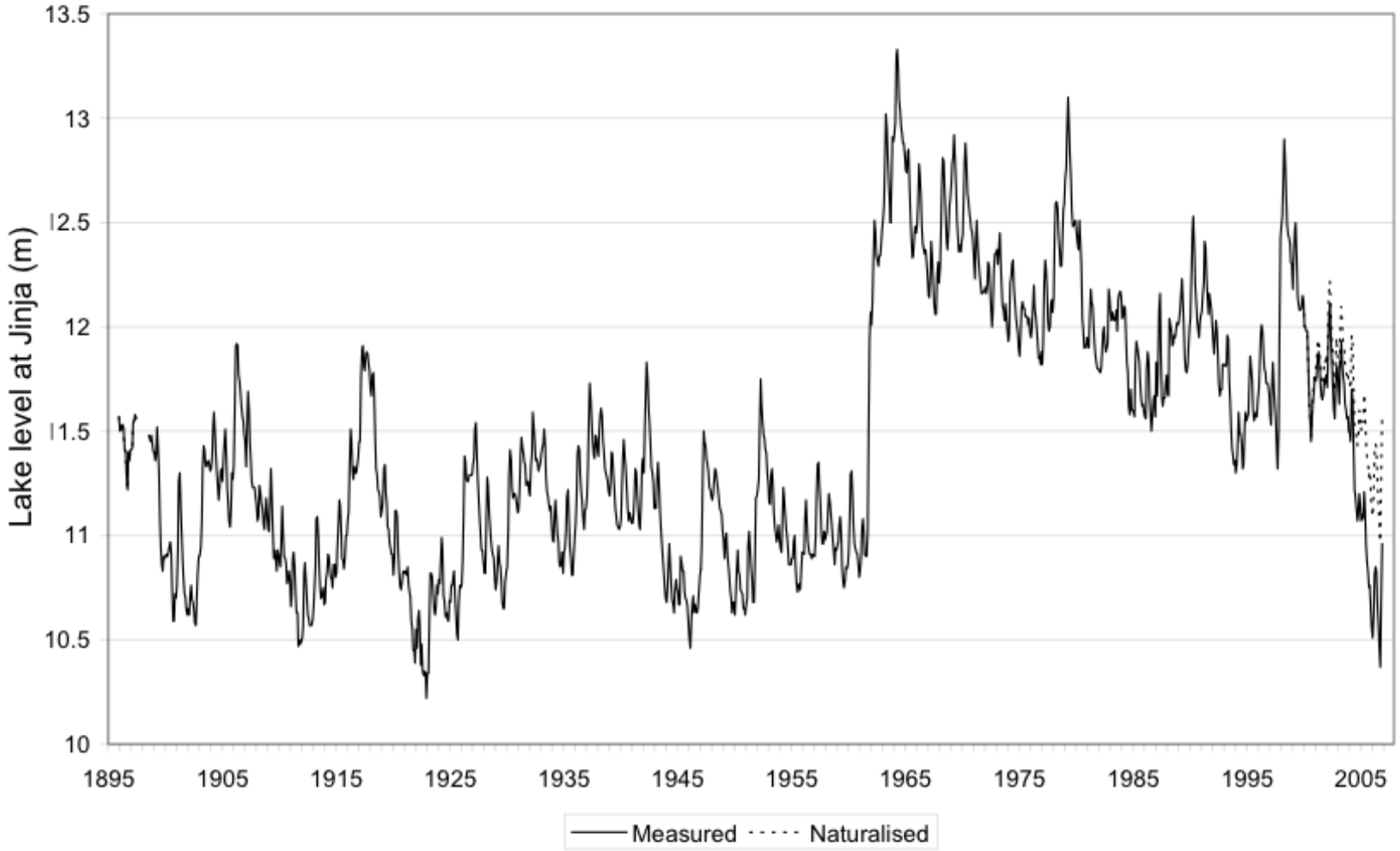
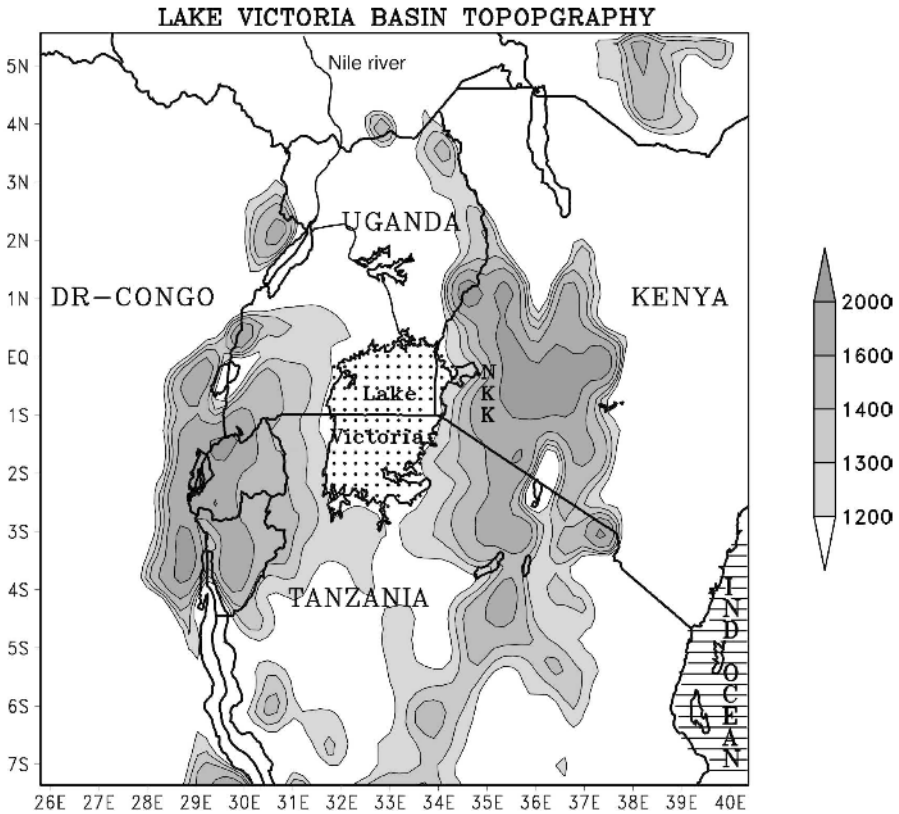
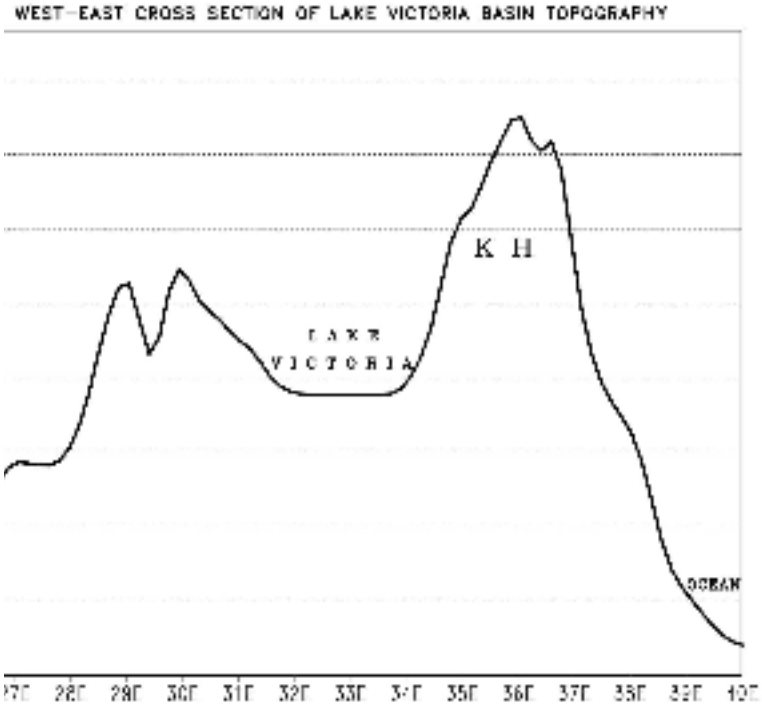


Fig. 2 Lake Victoria measured monthly levels, 1896–2006, including naturalised levels, 2000–2006.


LAKE VICTORIA BASIN TOPOPGRAPHY
Nile river
UGANDA
DR-CONGO
KENYA
Lake
Victoria
N
K
K
TANZANIA
INDIAN OCEAN
5N
4N
3N
2N
1N
EQ
1S
2S
3S
4S
5S
6S
7S
26E 27E 28E 29E 30E 31E 32E 33E 34E 35E 36E 37E 38E 39E 40E
2000
1600
1400
1300
1200


WEST-EAST CROSS SECTION OF LAKE VICTORIA BASIN TOPOGRAPHY
K H
LAKE
VICTORIA
OCEAN

Large-Scale and Regional Climate Modeling and Analysis

1. **Sea Surface Temperature (SST) variations cause shifts in jet streams, moisture advection, and resulting precipitation (started).**
   - 1.1 Determine the SST-precipitation lag correlation
   - 1.2 Compute Empirical Orthogonal Function (EOF) analysis of the correlated SST-Precipitation patterns to explain variance

2. **Regional climate modeling will quantify the bounds of uncertainty under current and projected climate and land use change.**
   - 2.1 Simulations of current and projected climate.
   - 2.2 Simulations of current and alternate land-use option

3. **Climate model variables:**
   - 3.1 Temperature (mean-daily minimum, maximum)
   - 3.2 Precipitation (frequency, intensity, duration, extent)
   - 3.3 Vapor pressure and wind speed
   - 3.4 Humidity and Fractional Cloudiness
   - 3.5 Other Variables

Analysis

1. Large-scale climate data analysis and regional climate and land-use system modeling (WRF-CLM) and analysis to quantify climate change for West Africa, East Africa, and Lake Victoria

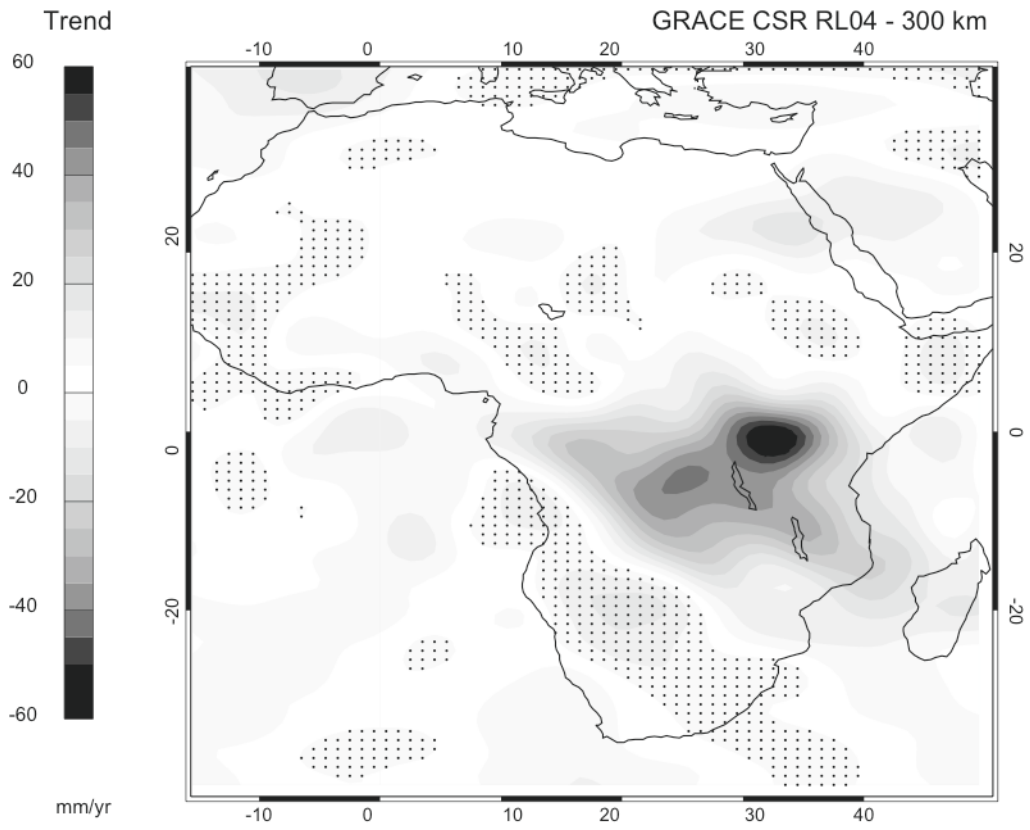
1. Calculate variability in runoff yield, precipitation, and groundwater for Lake Victoria sub-basins impacting the towns Masaka, Uganda, Bukoba, Tanzania, and Kisii, Kenya.

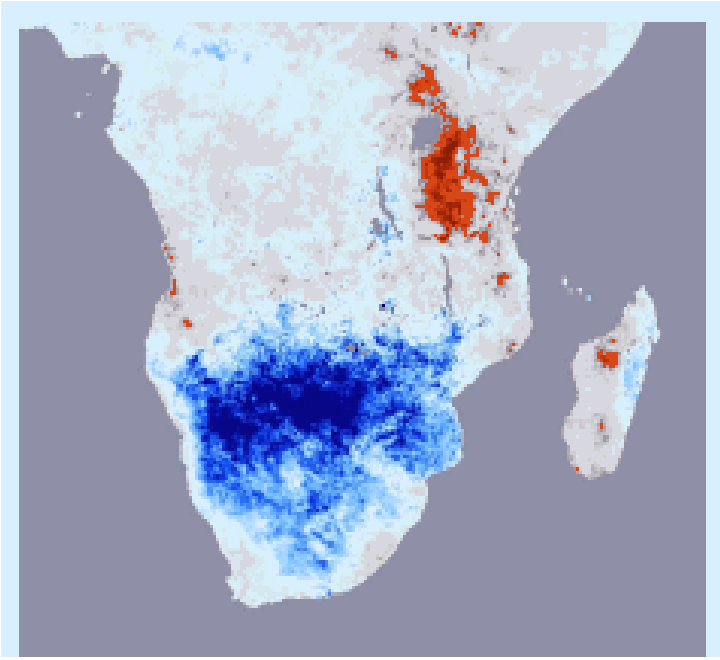
1. Application of the Water Evaluation and Planning (WEAP) model to the three pilot water utilities in Masaka, Bukoba, and Kisii. Quantify current and projected water demand, agriculture and irrigation use, and supply limits.

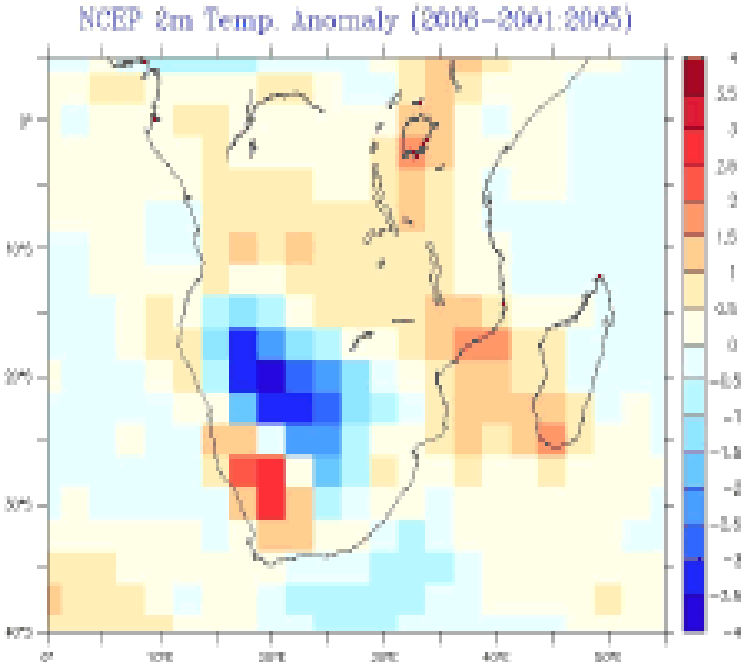
1. Update and advance climate analysis, and develop an economic and long-term water supply and demand analysis of investments in smaller and larger scale water utilities in African cities

Lake Victoria Precipitation

- It is unlikely that causes of the dramatic lake level fluctuations can be understood without accounting for the contribution from large-scale forcing to regional rainfall variability.
- Some Characteristics of Lake Victoria:
  - The seasonal cycle of rainfall is mainly controlled by the north-south migration of the intertropical convergence zone. The diurnal cycle is dominated by land/lake breeze circulations.
  - Bi-modal rainfall pattern (long rains in MAM with secondary short rains in OND).
  - Short rains account for majority of interannual rainfall variability.
- Lake Victoria provides an environment conducive for complex interactions and integrations between regionally induced and large-scale circulation systems:
  - Lake Victoria is large and diverse thus it produces regional-climates that are superimposed upon and interact with large-scale patterns. As a result even diurnal circulations are impacted by large-scale forcings such as SSTs.
- As a result of these characteristics we are interested in major forcing mechanisms on OND rainfall.

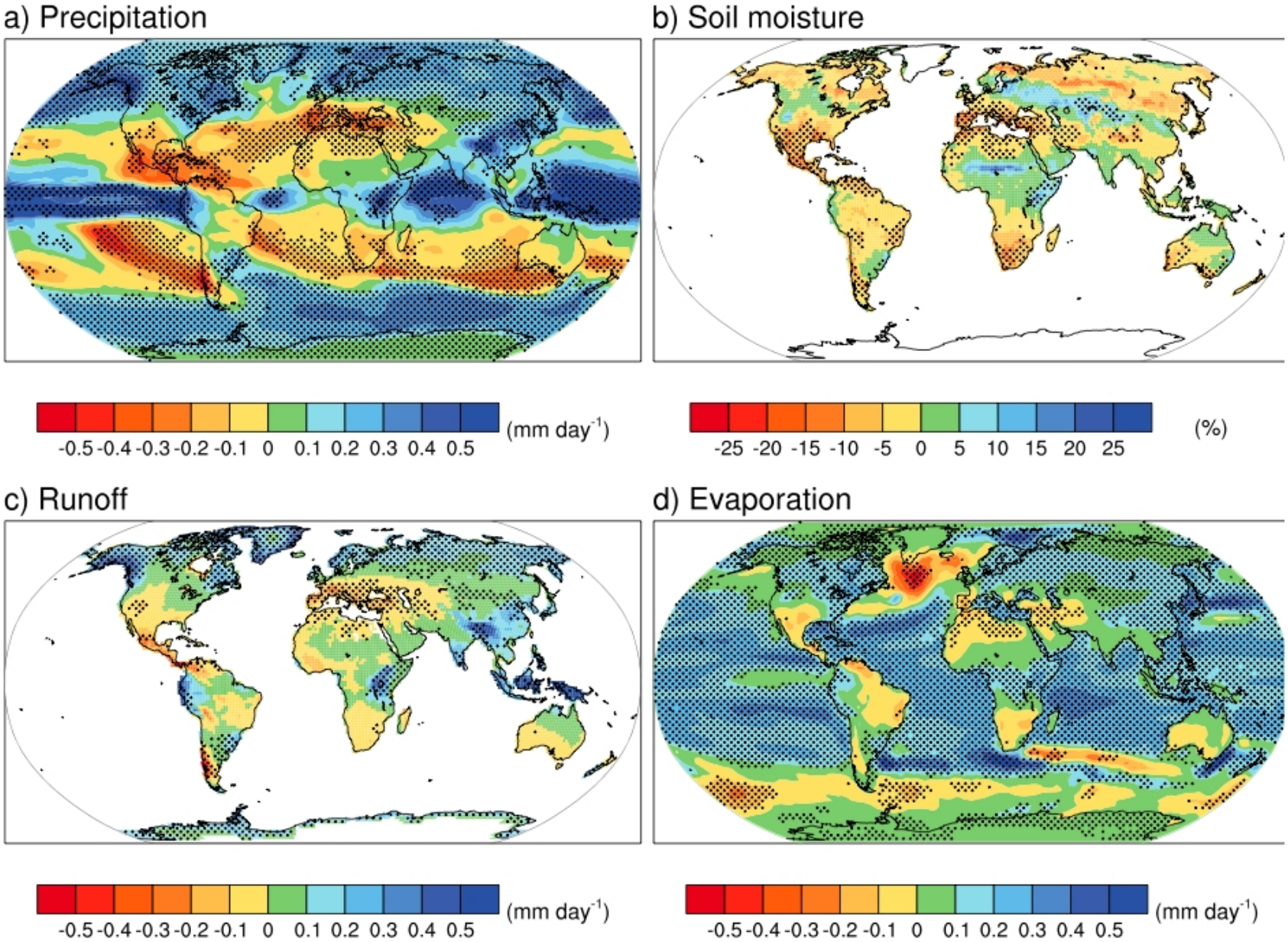

Trend
GRACE CSR RL04 - 300 km
60
40
20
0
-20
-40
-60
mm/yr
-10
0
10
20
30
40
20
0
-20

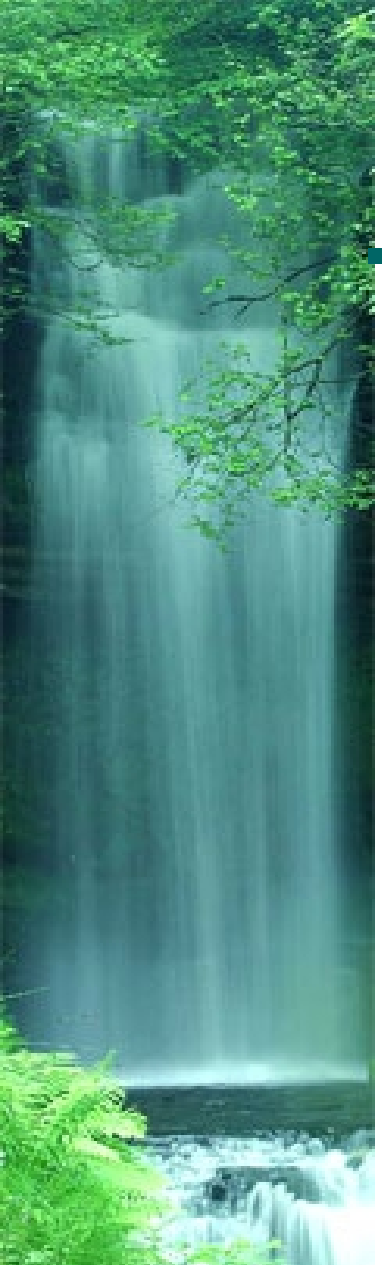




MODIS observations of surface temperature during the short rains of east Africa for Oct-Nov-Dec (left), and NCEP reanalysis (right). Anomalies are based on the difference, 2005 minus average of 2001-2005.

IPCC AR4 Climate Change (2099-2080) – (1999-1980), SRES A1B
Lake Victoria Basin will have more extreme precipitation, increased evaporation,

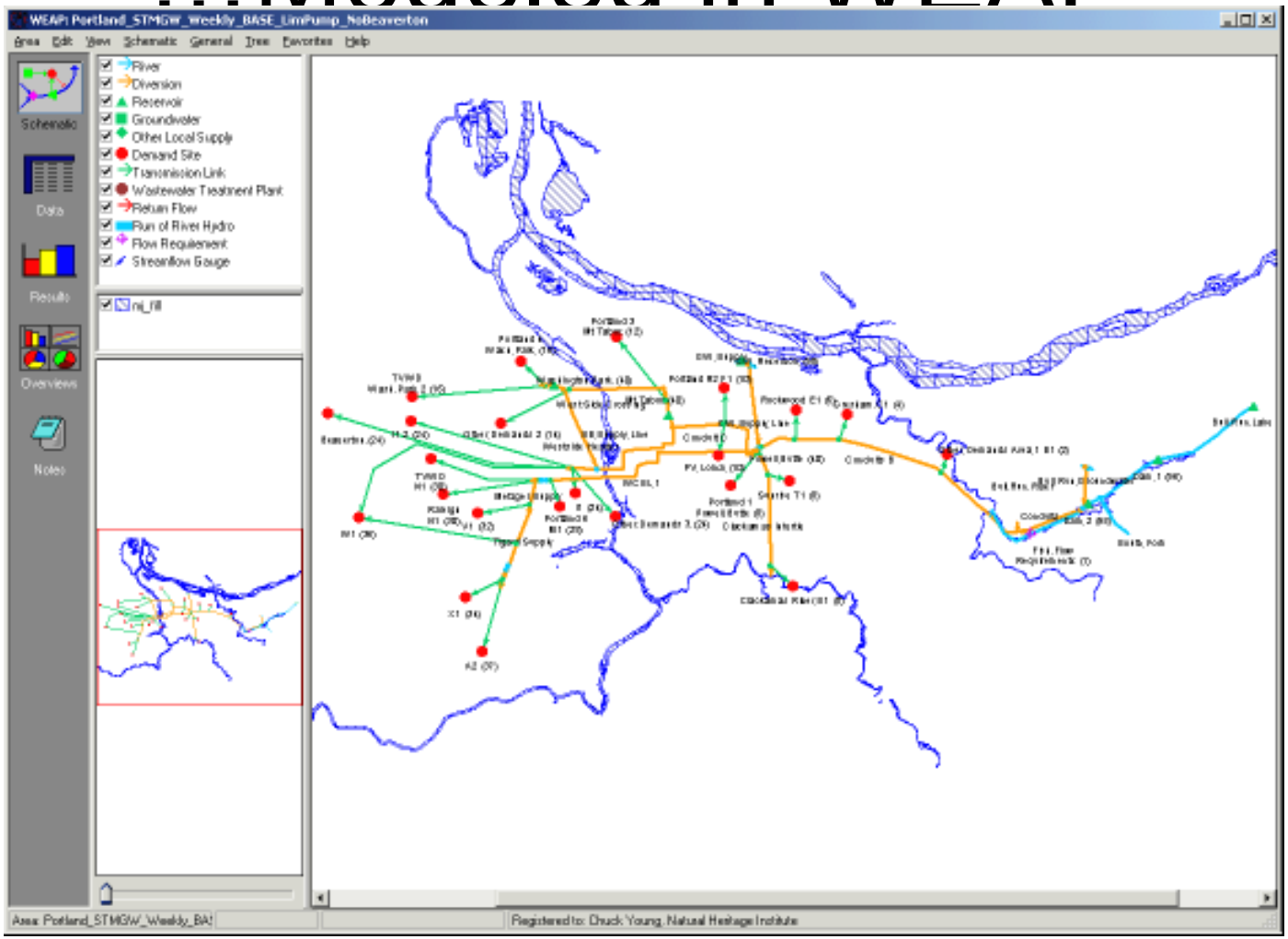




WEAP

- Sectoral demand analyses
- Water conservation
- Water rights and allocation priorities
- Groundwater and streamflow simulations
- Reservoir operations
- Hydropower generation
- Pollution tracking
- Ecosystem requirements
- Climate change impact and adaptation analysis

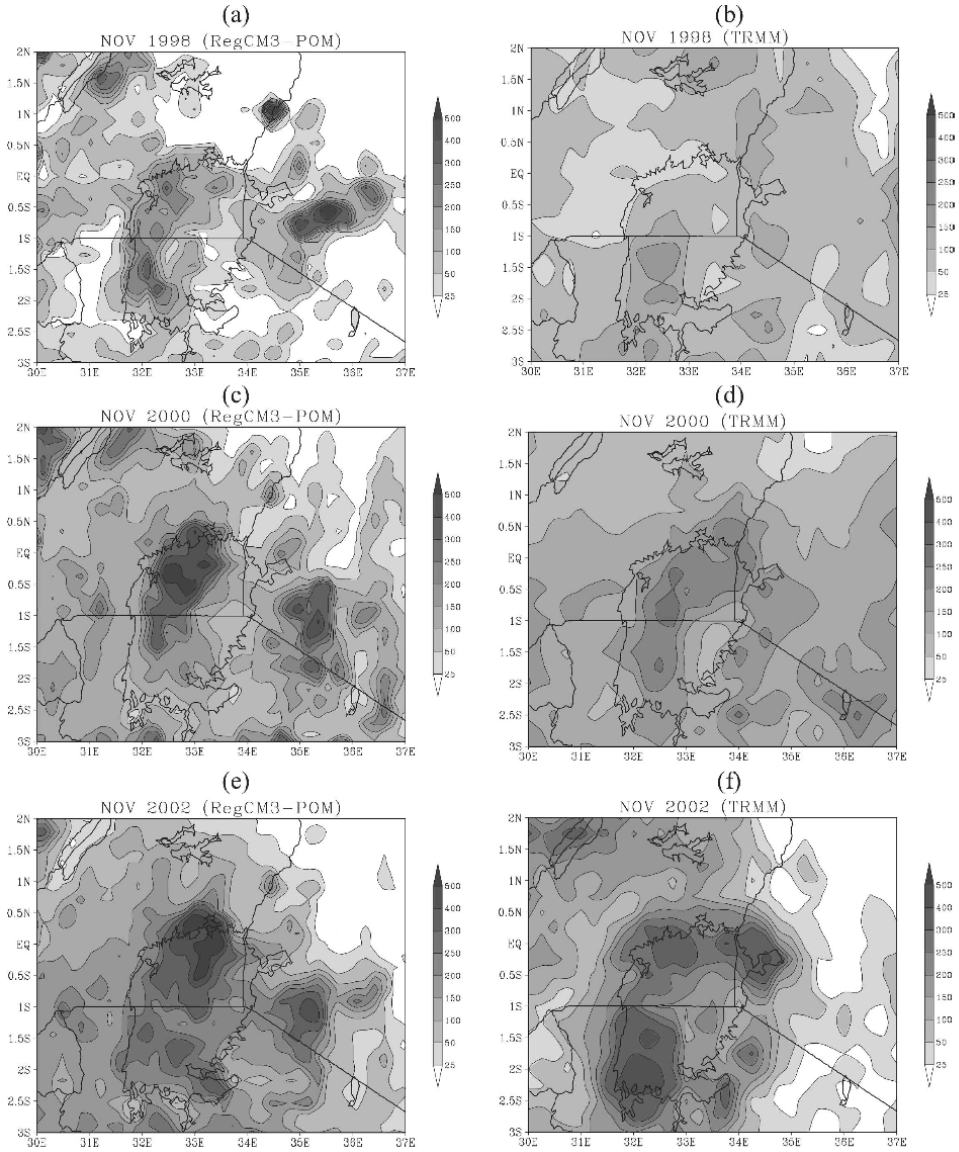
…Modeled in WEAP



The coupling of large water bodies in Eastern Africa and the regional climate is not well understood. A large proportion of the surface area is occupied by the three largest lake basins of Eastern Africa (Malawi, Tanganyika, and Victoria) and the west Indian Ocean sector.

The climatic effects of these water surfaces may further be amplified through land/atmosphere coupled processes and extend up to 300km way from the coastline.

Lake Victoria hydrodynamics plays a critical role in determining the coupled variability of the lake and the regional lake basin climate


(a)
NOV 1998 (RegCM3–POM)
(b)
NOV 1998 (TRMM)
(c)
NOV 2000 (RegCM3–POM)
(d)
NOV 2000 (TRMM)
(e)
NOV 2002 (RegCM3–POM)
(f)
NOV 2002 (TRMM)
2N
1.5N
1N
0.5N
EQ
0.5S
1S
1.5S
2S
2.5S
3S
30E
31E
32E
33E
34E
35E
36E
37E
500
400
300
250
200
150
100
50
25

Climate Viability and Change: 45% Lake Victoria Water Levels

- The severe weather extremes are to LV are increased evaporation, floods and droughts

- Equatorial Glaciers will completely melt away by ~2020, including Mt. Kilimanjaro, decreasing runoff and water availability.

- Sea Surface Temperature (SST) has increased globally, including the teleconnected equatorial Pacific Ocean and Indian Ocean, directly impacting precipitation and drought over the Lake Victoria domain.

- The hydrologic cycle is observed to be intensifying, with jet streams moving northward, likely bringing more flood events to LV.

- Evidence suggests the Indian Monsoon circulation may weaken in response to tropospheric warming, changing moisture flux into East Africa.

Project Components

1. **Scoping Study**
    1. Climate Variability and Change Analysis (**LBNL; started**)
    2. Climate Change Impacts Analysis (**LBNL**)
    3. Stakeholder Consultations and site visits (**Re-Solve, Climate XL; completed**)

1. **Analysis**
    1. Water resource management, operations, and planning in response to climate change vulnerability (**LBNL, SEI**)
    2. Infrastructure investment analysis of small and large water utilities (**LBNL**)

1. **Review Results**
    1. Criteria for prioritizing options (**Re-Solve, Clime XL**)
    2. Workshop recommendation measures for each utility (**Re-Solve, Clime XL**)

1. **Implementation** of adaptation measures for each utility and provide climate change guidebooks or toolkits (**Re-Solve, Clime XL**)

1. **Follow-Up** Monitoring and Project Evaluation (**Re-Solve, Clime XL**)

1. **Project Auditing** and Progress (**ASE, Clime XL**)