KATHOLIEKE UNIVERSITEIT
LEUVEN

Relation between hydro-climatic extremes and atmospheric circulation patterns in the Nile basin

Meron Teferi Taye and Patrick Willems

COST Action 733 - Final workshop
Nov 22 – 24

Introduction

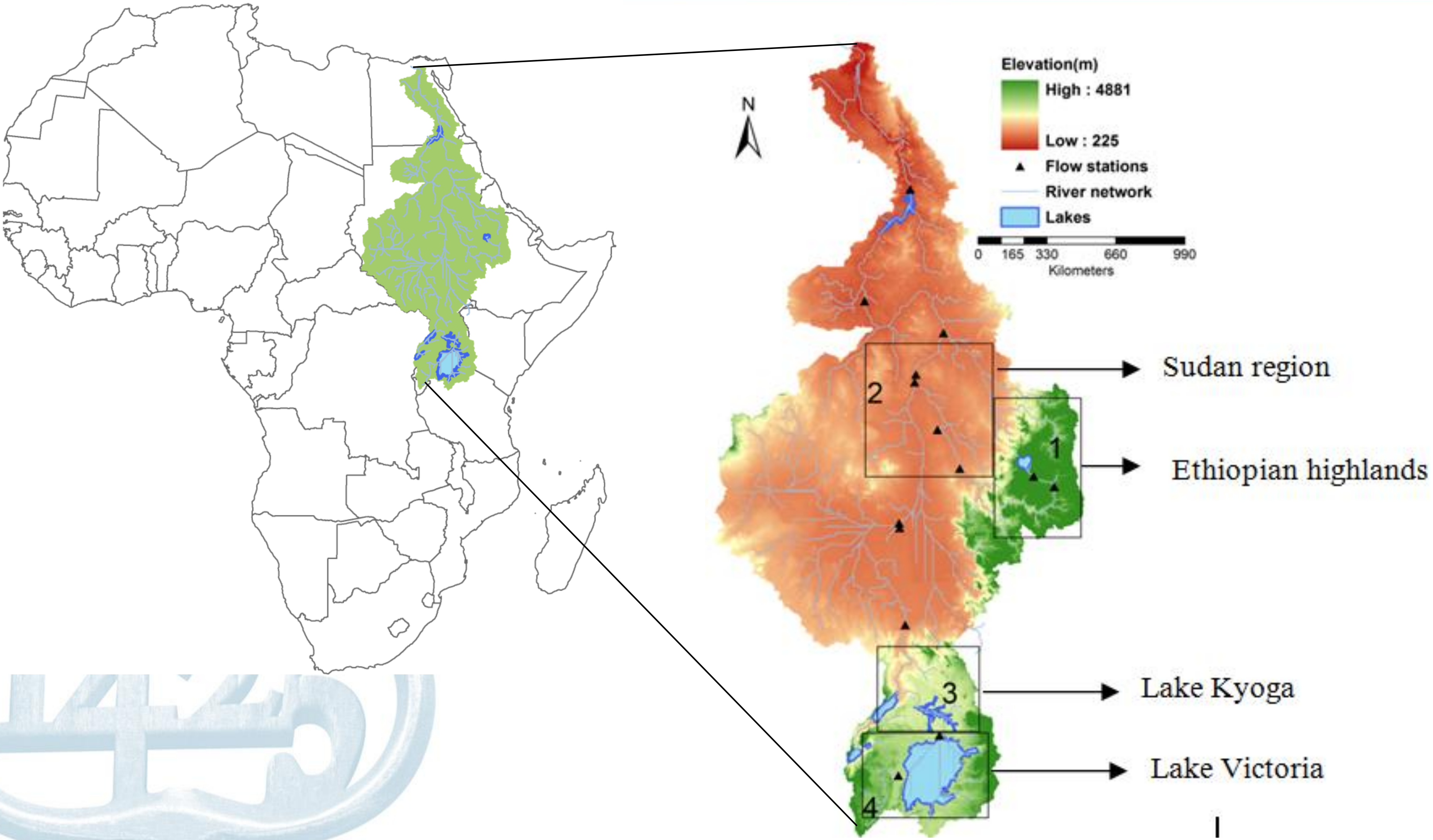
- Extreme events are major concern to Africa
  - Floods and droughts
- Sensitive to rainfall variability => hydrological variability
  - Catchment selected => the Nile basin
- Research questions
  - Are these variability random or persistent in time?
  - Which periods show significant oscillation highs and lows?
  - Is it possible to find a link between extreme hydro-climatic events and large scale atmospheric variables?
- Sea Level Pressure fields => as indicator
- Hydro-climatic extremes => rainfall/river flow extremes

Data

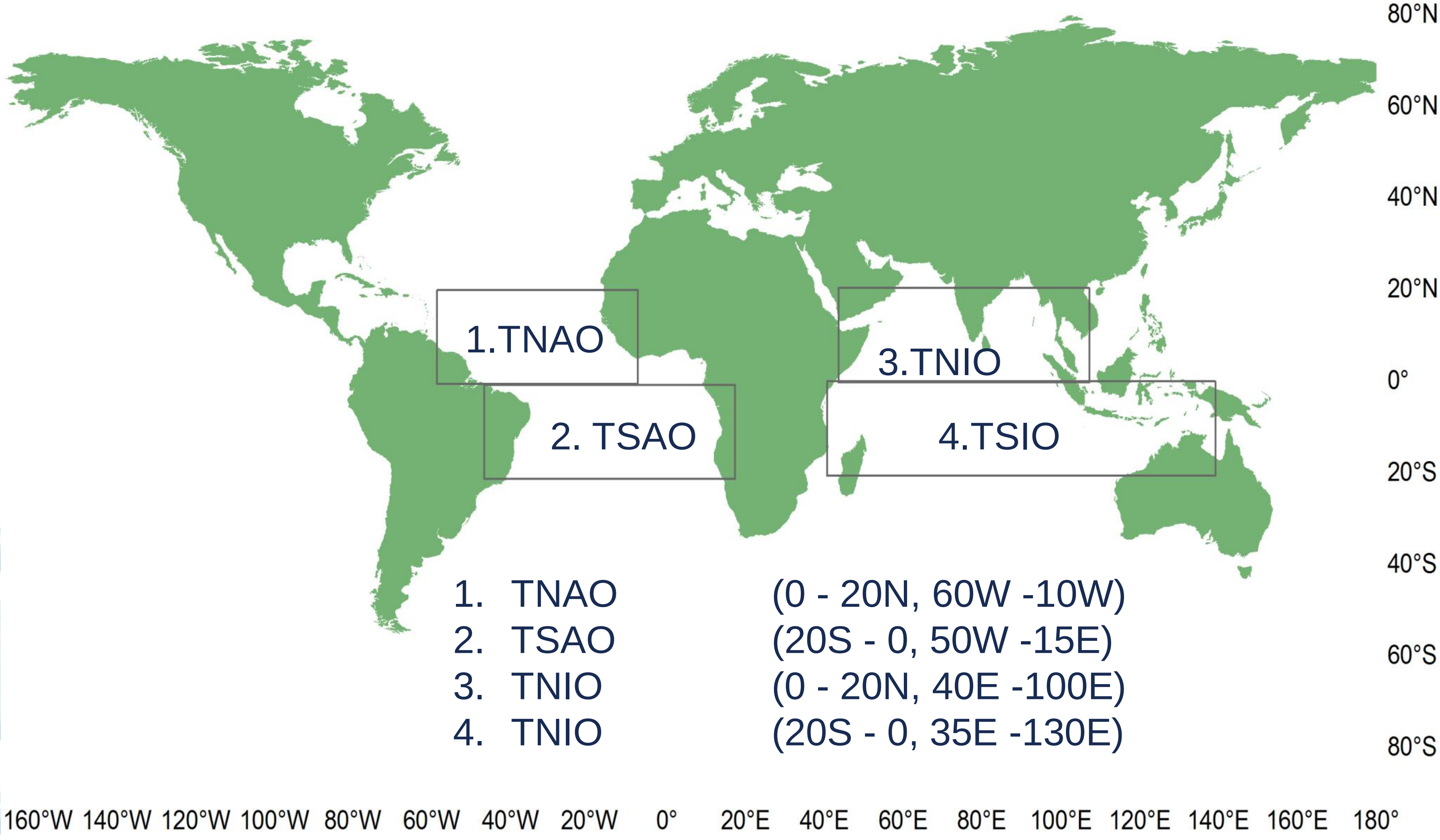
- River flows
  - Major stations along the Nile river
- Rainfall
  - Gridded data (http://badc.nerc.ac.uk/data/cru/)
  - Station data
- Sea Level Pressure (SLP)
  - Tropical Atlantic Ocean (southern – northern)
  - Tropical Indian Ocean (southern – northern) (www.metoffice.gov.uk/hadobs)
- Southern Oscillation Index (SOI)
  - ENSO index (SLP difference in Pacific Ocean) (http://badc.nerc.ac.uk/data/cru/)

Annual & monthly

Study area and rainfall data coverage



Grids for SLP data



1. TNAO (0 - 20N, 60W -10W)
2. TSAO (20S - 0, 50W -15E)
3. TNIO (0 - 20N, 40E -100E)
4. TNIO (20S - 0, 35E -130E)

Method for Oscillation pattern analysis

- Empirical statistical analysis
  - To find (multi-) decadal oscillation patterns
- Calculating relative change in extreme values
  - Quantiles with the same return period
- Two time series are required
  - A reference period
    - The total observed time series
  - A block period
    - A subseries of the total time series
- A block period = 10 years

Anomaly computation

- If *i* is a rank number, for *i* = 1, 2, 3 ... n
  - $X_1 \geq X_2 \geq X_3 \geq \ldots \geq X_n$ => the ranked extreme values
- Block period (*b*) & Total period (t)
  - Empirical return period (R_b) = *b/i*
  - Empirical return period (R_t) = *t/i*
- Quantiles for block & total period
  - $X(b), X(b/2), \ldots, X(b/i),$
  - $X_r(t), X_r(t/2), \ldots, X_r(t/i).$
- A relative change is the ratio of block period to total period quantiles

$$X(b)/X_r(t),\ \ X(b/2)/X_r(t/2), \ldots, X(b/i)/X_r(t/i)$$

Anomaly computation

- Matching the return periods $i^* = \frac{t}{b} * i_b$
  - *i** – the rank number that corresponds to same return period as that of the block period quantile
  - i_b – the rank number of block period quantiles
  - *t* – total number of years of the time series
  - *b* – *is* the number of years in block period
- Anomaly of the block period (b)
  - Average of the most extreme events
    - 3 extreme values per year
- Sliding window approach – sliding by 1 year
  - To see the temporal variation of the anomaly

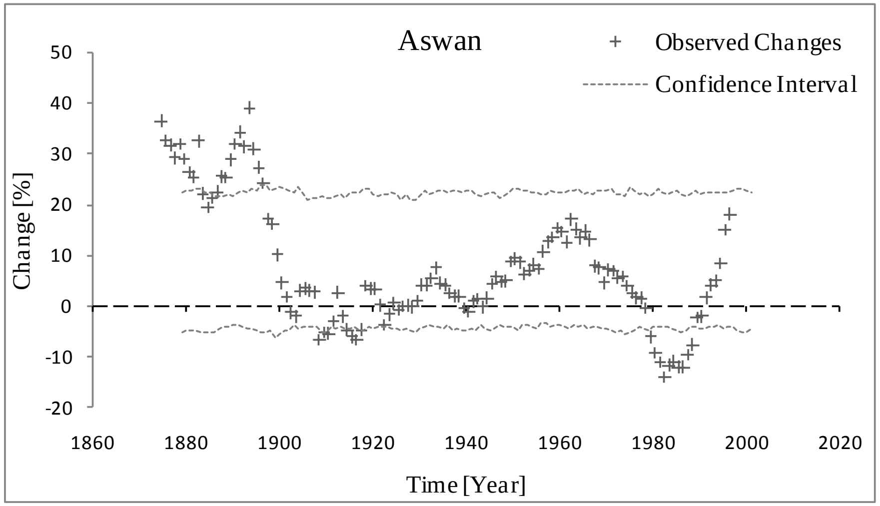
Monte Carlo confidence intervals

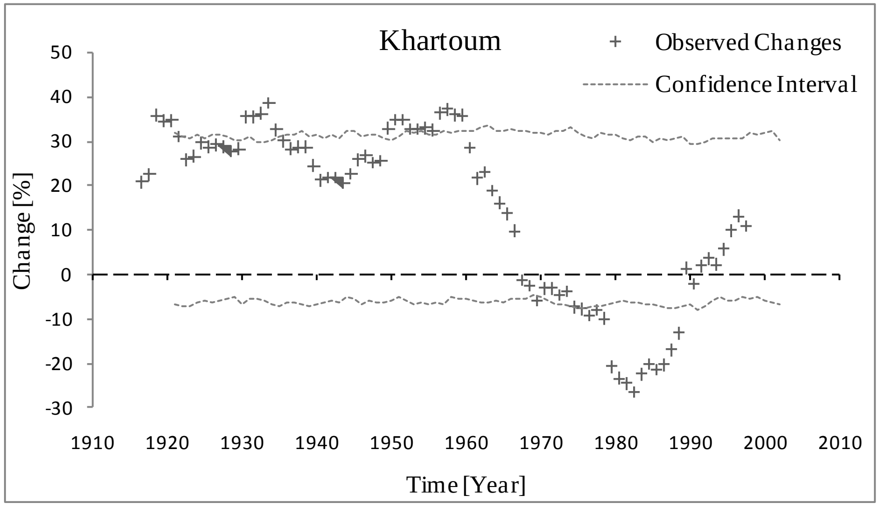
- To test statistical significance of the variation
  - Monte Carlo confidence intervals
- The null hypothesis
  - There is no persistence in time for the oscillation (no trends or multi-decadal oscillations)
- The nonparametric bootstrapping method
  - Empirical data => to generate random samples for each block
  - 1000 Monte Carlo runs executed
    - Generates 1000 possible anomaly factors
- The upper and lower limit of the confidence interval
  - Based on significance level of interest => 5%

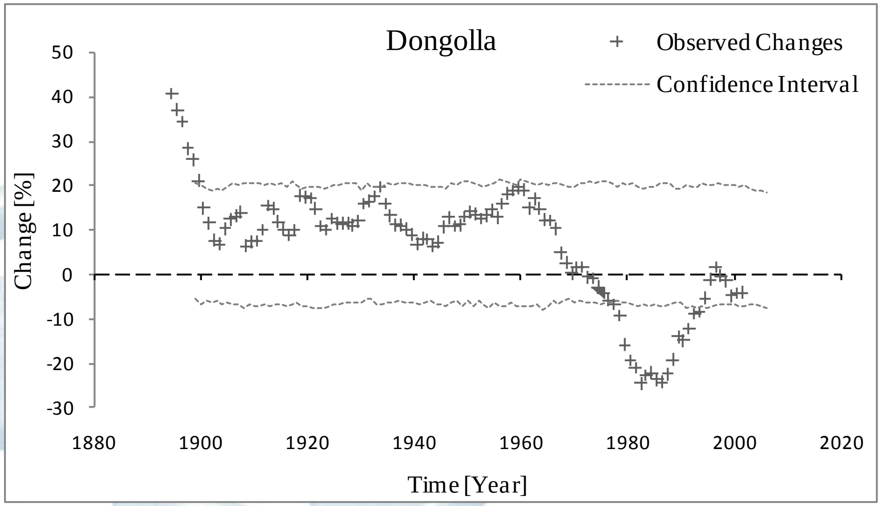
Results and discussions

- The null hypothesis of no persistence in time (no trends) in the annual extreme river flow oscillations
  - Rejected

Main Nile and Blue Nile



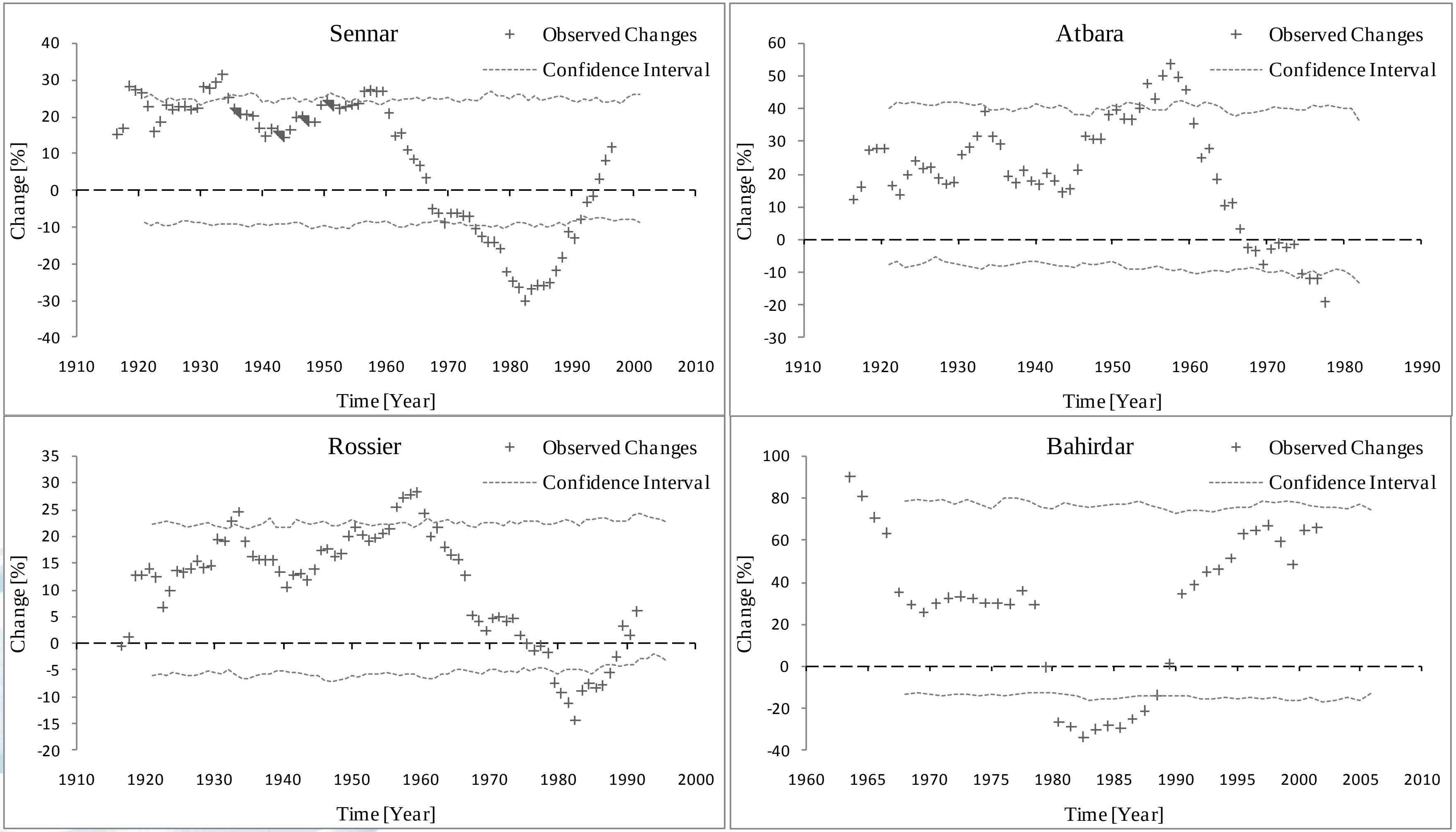




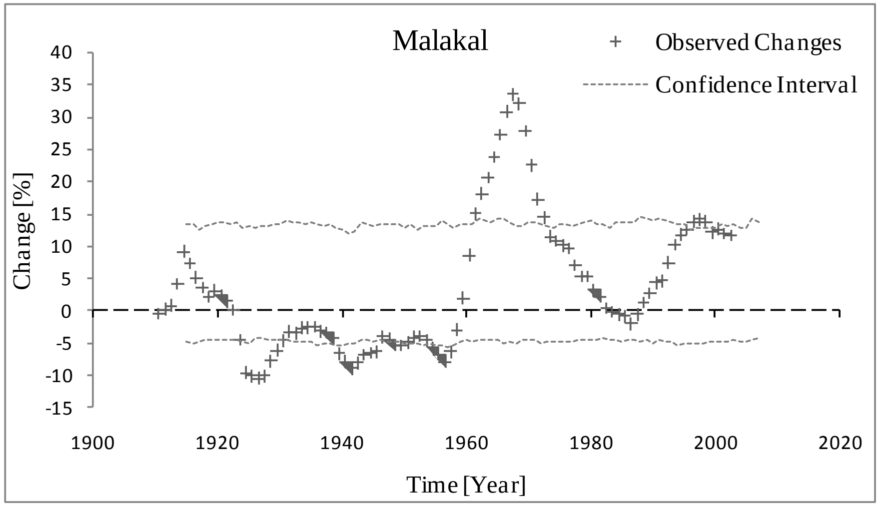
- Annual time step results
- 1930s – decreasing trend
- 1940s to 1960s – increasing trend
- 1960s to 1980s – decreasing trend
- 1990s – increasing trend

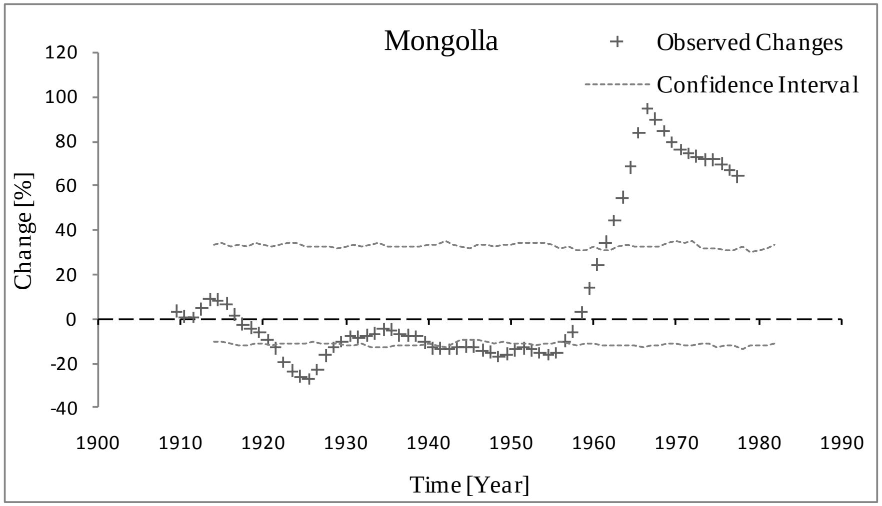
- The 1980s – statistically significant oscillation lows

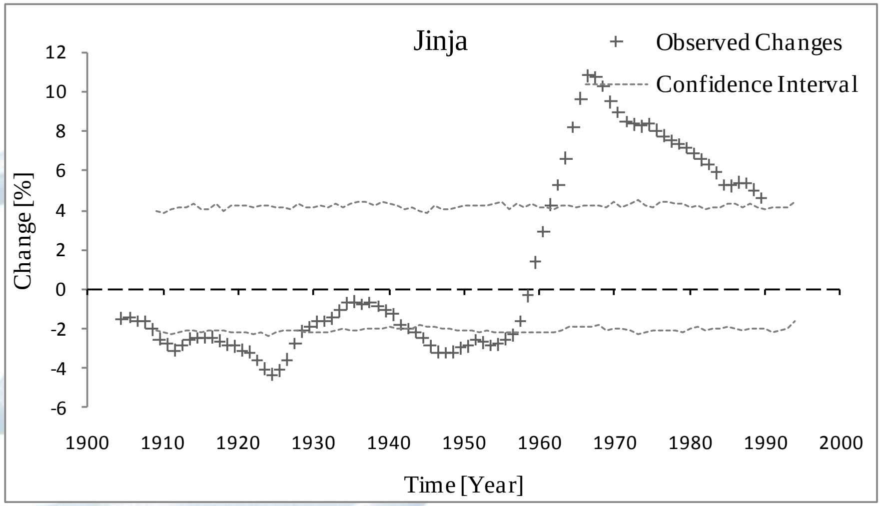
Blue Nile and Atbara



White Nile





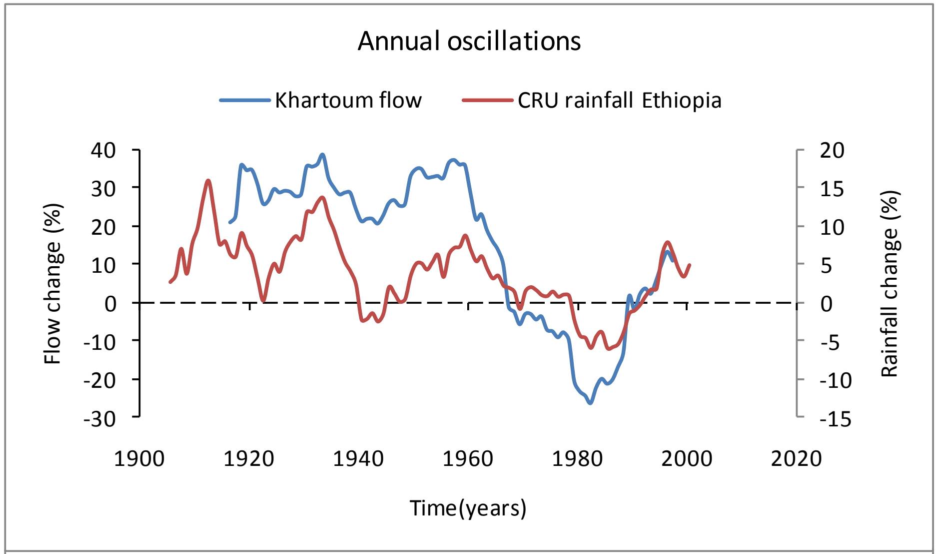


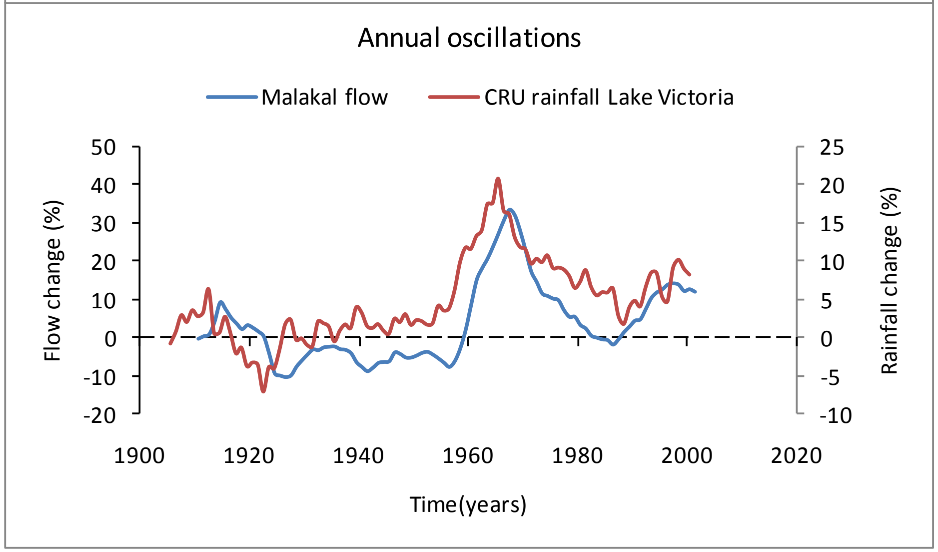
- 1940s – decreasing trend
- 1960s – increasing trend
- 1970s & 1980s – decreasing trend
- 1990s – increasing trend

- The 1960s – statistically significant oscillation highs

Rainfall Vs river flow

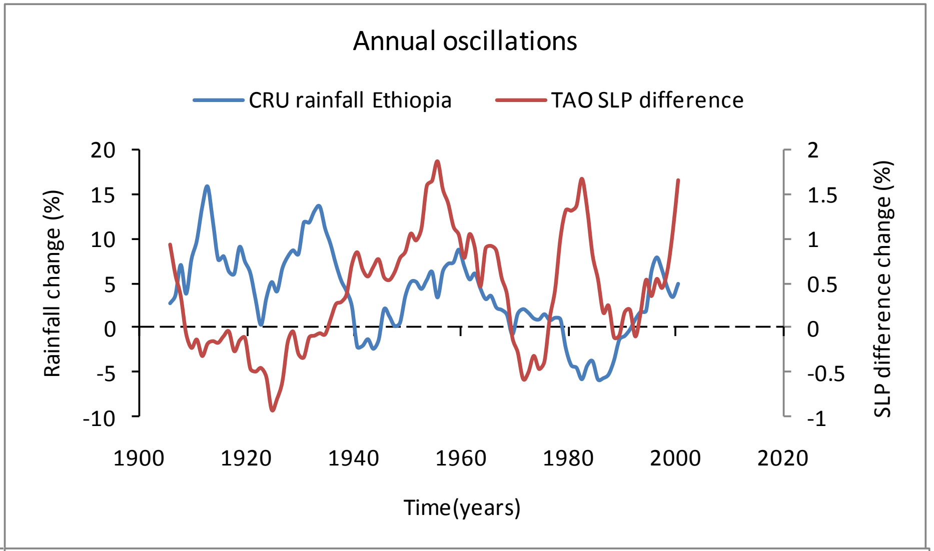
- Links between extremes were identified by looking pattern similarity
- Similar patterns
  - rainfall & river flow
- Examples
  - Khartoum => Blue Nile
  - Malakal => White Nile
- Rainfall oscillations
  - Main driving factor for river flow oscillations

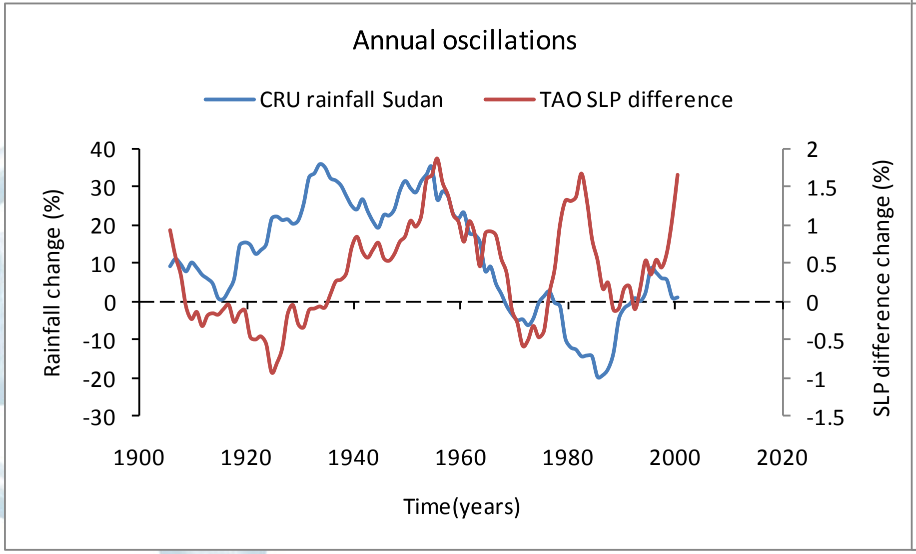


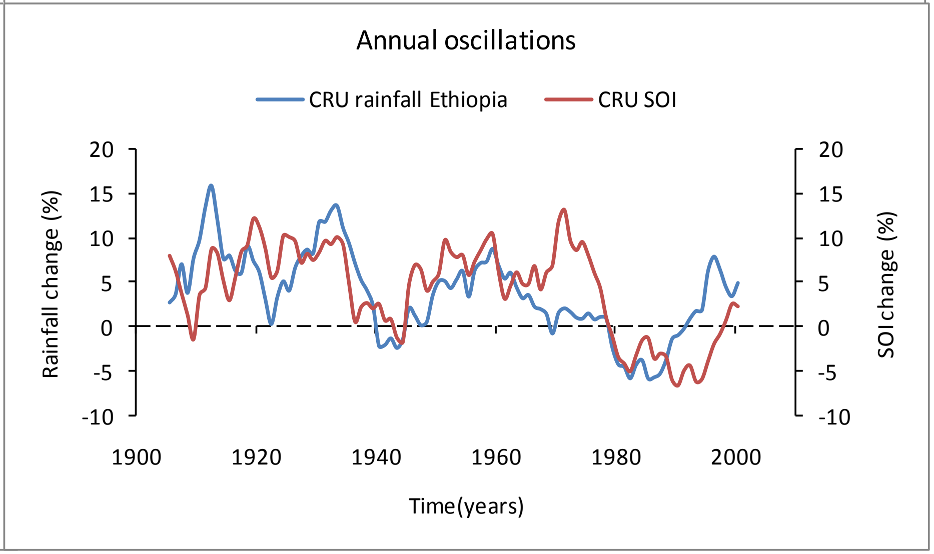


Rainfall Vs SLP difference

- Similarity between rainfall extremes in the Blue Nile and SLP difference of Tropical Atlantic Ocean
- Rainfall extremes have stronger relationship with SOI during less extreme rainfall periods (dry periods)

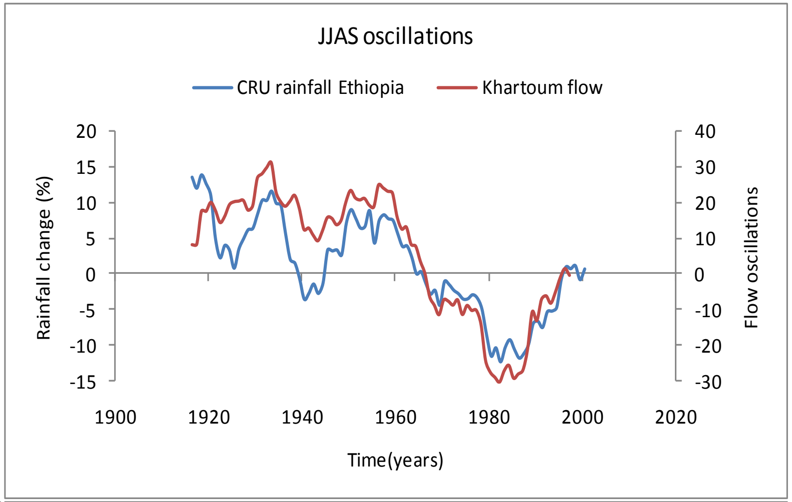


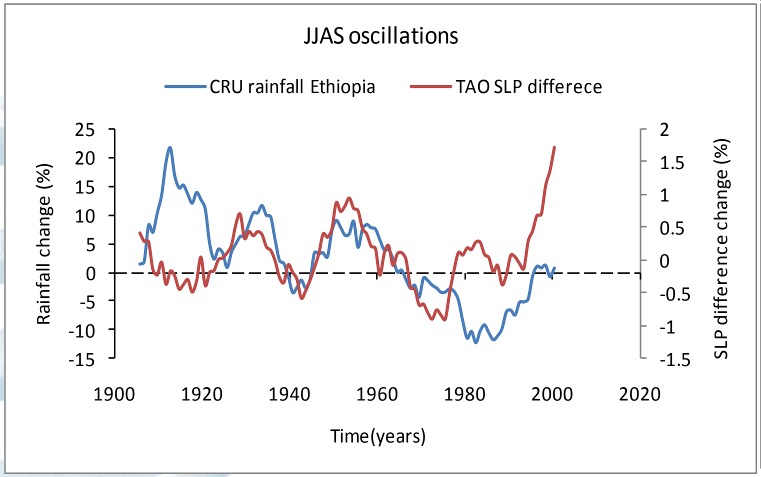


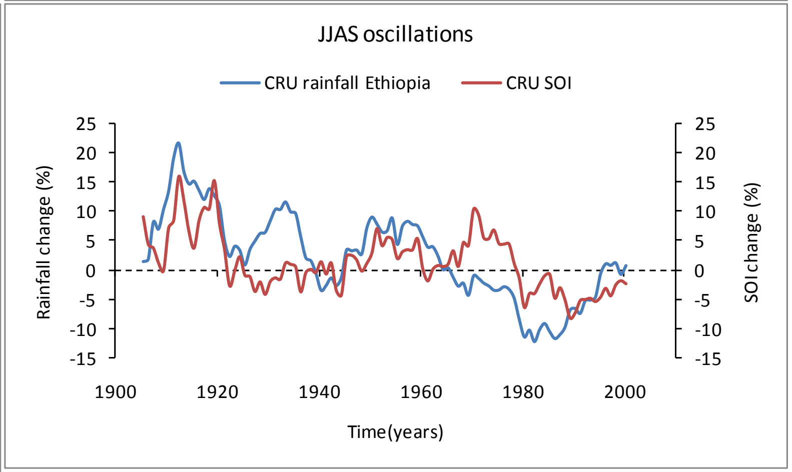


Seasonal scale

- JJAS – Blue Nile (Main rainy season)
- Strong similarity between
  - Rainfall over the Ethiopian highlands and flow at Khartoum
  - Rainfall extremes and TAO SLP difference during oscillations highs
  - Rainfall extremes and SOI during oscillations lows

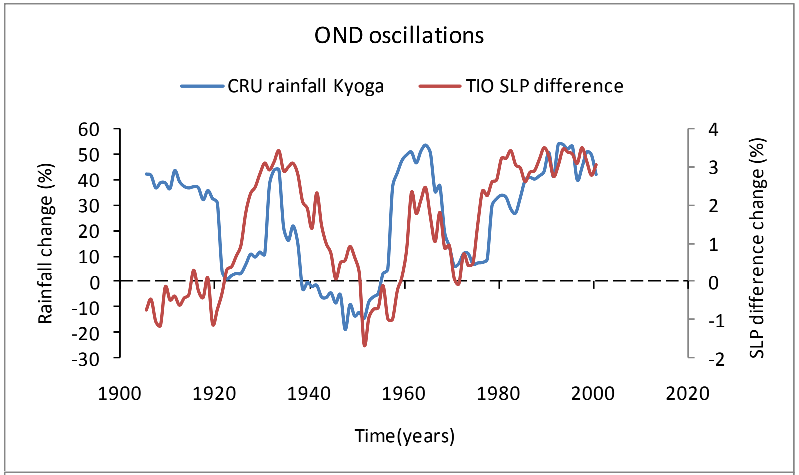


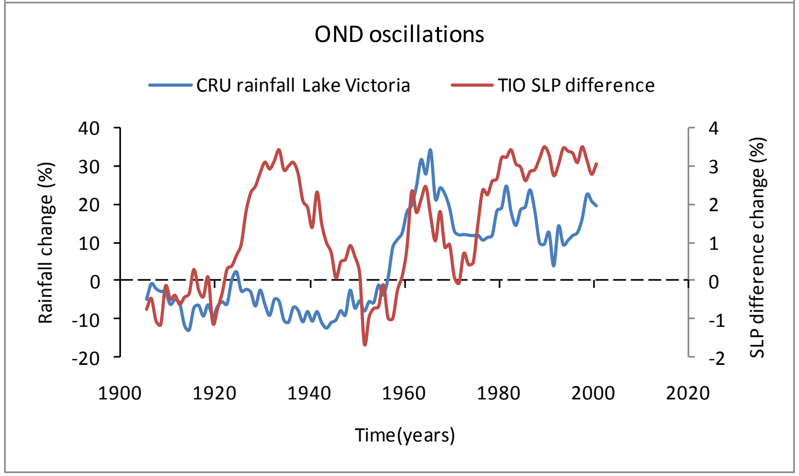




Seasonal scale

- OND – White Nile (short rainy season
- Strong similarity of pattern between
  - Rainfall extremes in Lake Kyoga region and TIO SLP difference
  - Rainfall extremes in Lake Victoria region during the 1960s and TIO SLP difference
- Strong influence of Indian Ocean in OND season

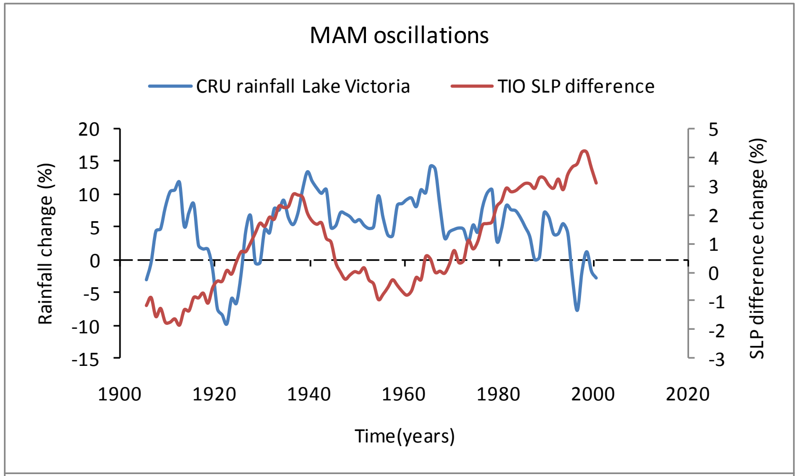


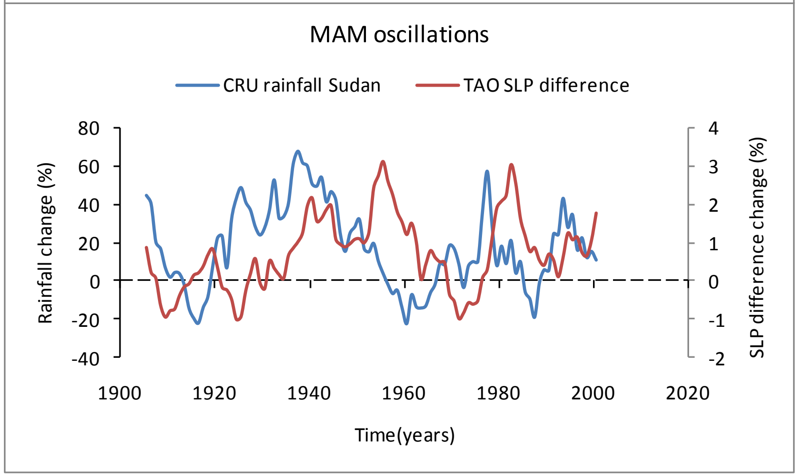


Seasonal scale

- MAM – White Nile (Long rainy season)
- No pattern similarity between
  - White Nile catchments and Indian ocean or Atlantic ocean

- Rather the Sudan part of Blue Nile shows similar pattern with TAO SLP difference
  - The SLP oscillations precede the rainfall oscillations





Summary

- Variability in rainfall/river flow extremes is not random
  - Oscillation patterns showed persistence in time
- Two patterns identified in the Nile basin
  1. Blue Nile, Atbara & Main Nile
  2. White Nile
- Periods with significant oscillation highs and lows identified according to the catchments
  - Significant oscillation lows
    - Late 1970s & beginning of the 1980s
    - Blue Nile, Atbara & Main Nile
  - Significant oscillation highs
    - Beginning of the 1960s
    - White Nile

Summary

- Possible links noticed between extreme hydro-climatic and atmospheric variables
- Blue Nile region
  - Relatively strong links in the JJAS & MAM seasons for high extremes with Tropical Atlantic Ocean
  - Strong similarity between SOI and less extreme rainfall periods
- White Nile region
  - Relatively strong links in the OND season with Tropical Indian Ocean

Conclusions

- Blue Nile region
  - Influenced by Tropical Atlantic Ocean during high extreme events
  - Higher influence of El Nino during less extreme events (dry periods)
- White Nile region
  - Influenced by Tropical Indian Ocean during the OND season
- Main Nile
  - Strongly linked with Blue Nile oscillation patterns, thus influenced by similar factors

THANK YOU