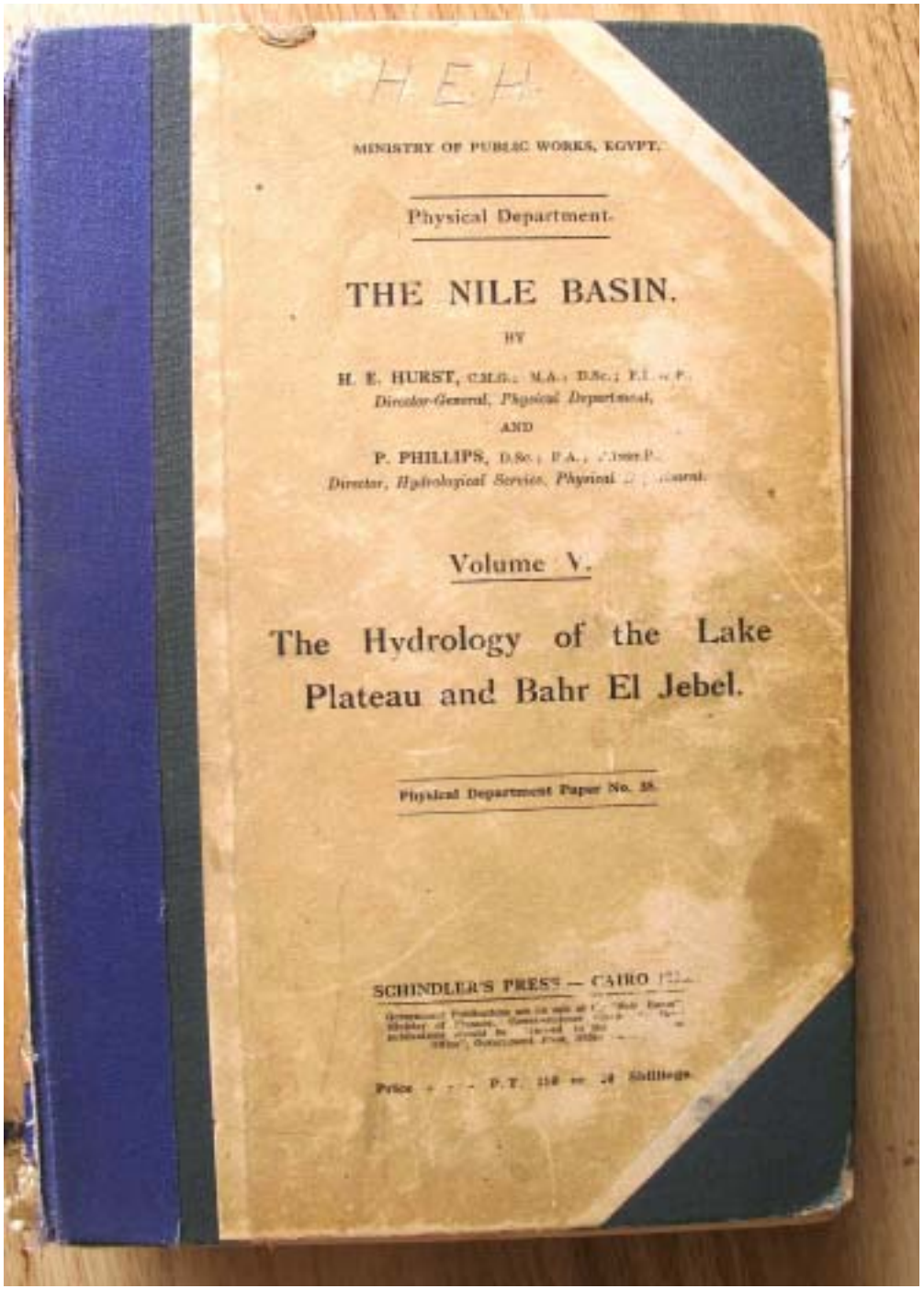
FACETS OF UNCERTAINTY

Kos Island, Greece
17-19 October 2013

STAHY '13
Round Table for H.E.Hurst

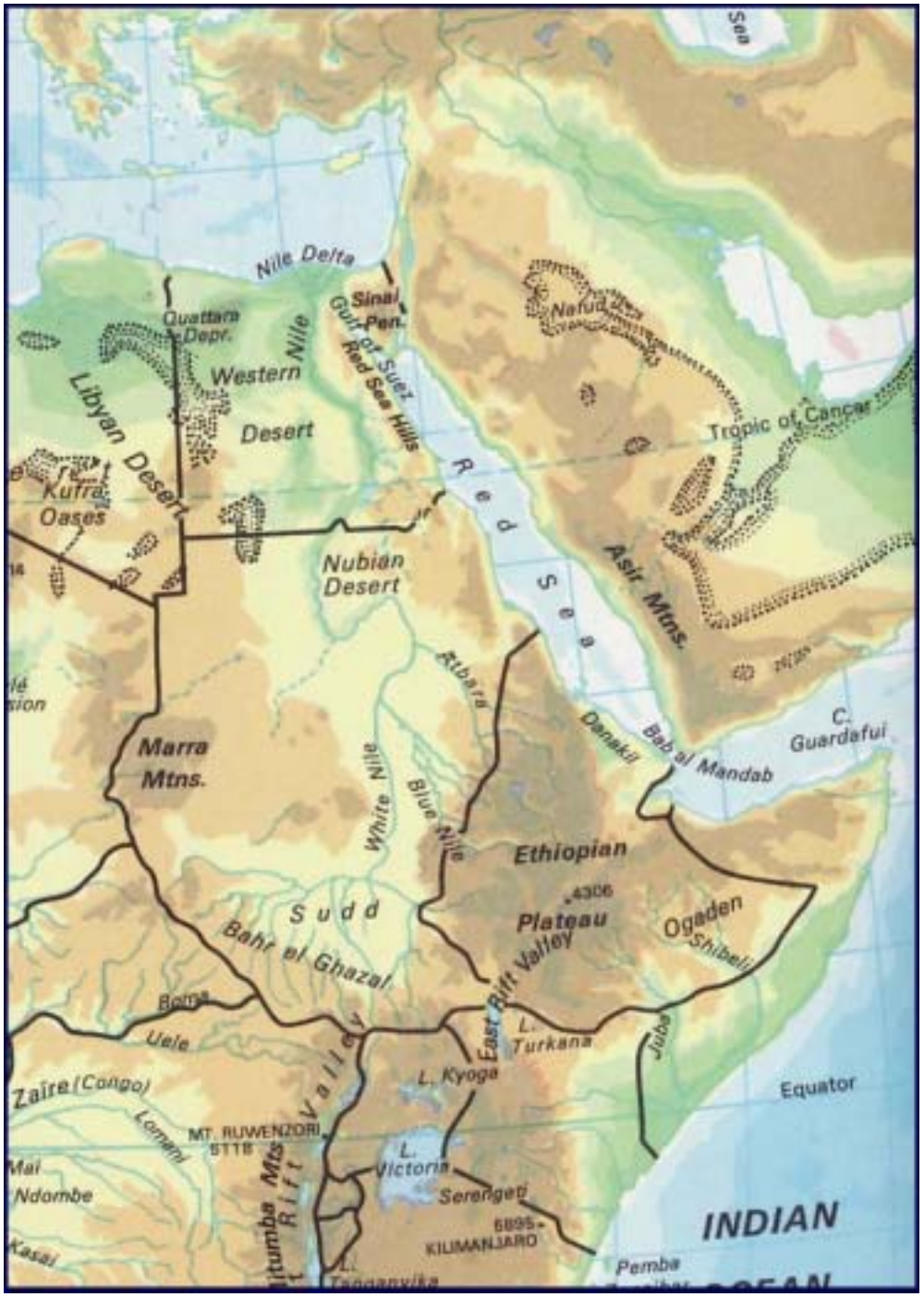
John Sutcliffe (UK)



Harold Hurst: His Career and Legacy

John Sutcliffe
Emma Brown

THE NILE BASIN



OUP Canada

HURST'S CAREER

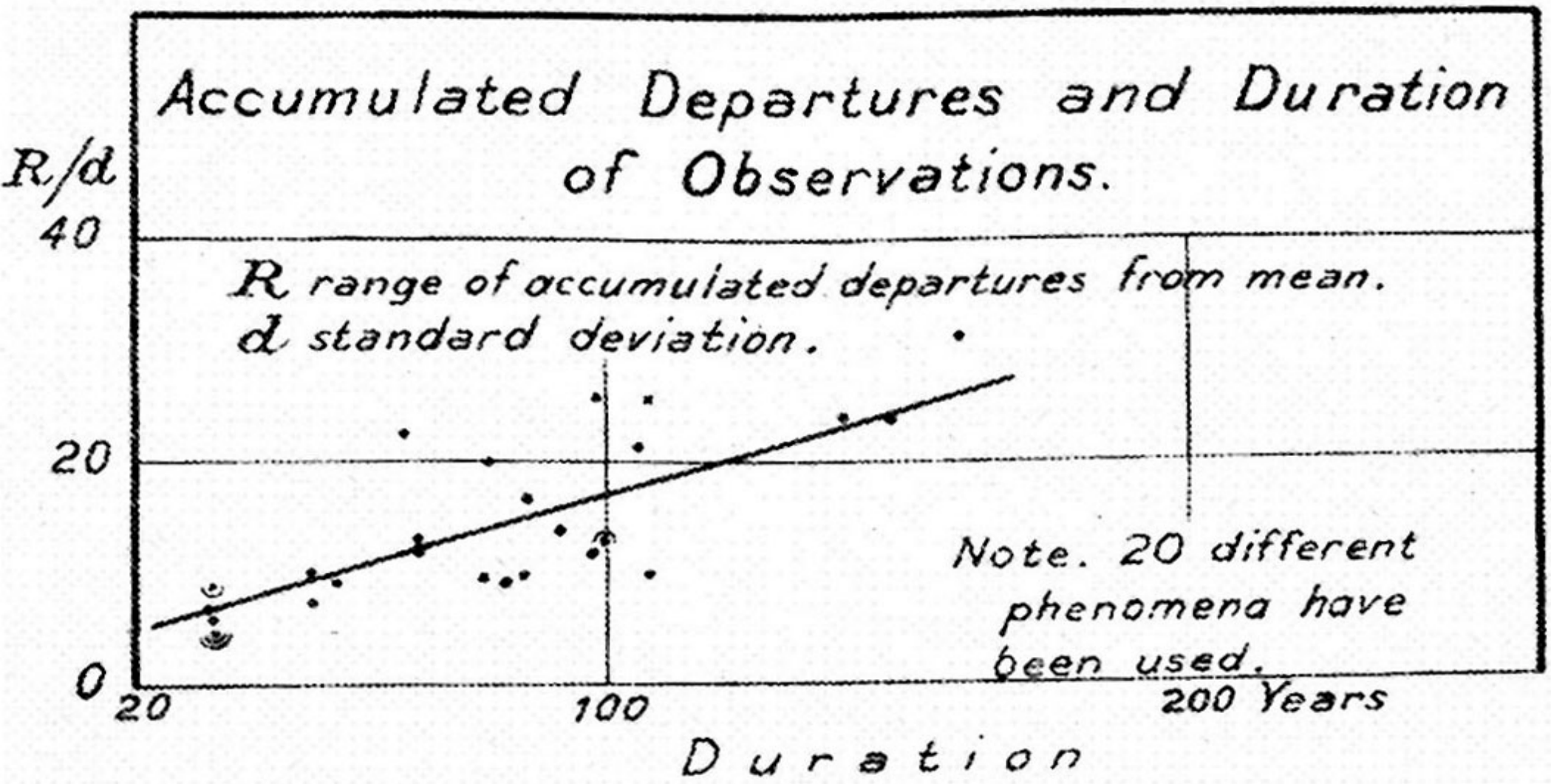
- Harold Hurst served Egypt from 1906 to 1968
- The Physical Department collected hydrological data from the whole Nile Basin
- 100 river gauges in Egypt, Sudan and East Africa
- Flows and rainfall records in over 60 volumes of *The Nile Basin*

THE EQUATORIAL NILE PROJECT

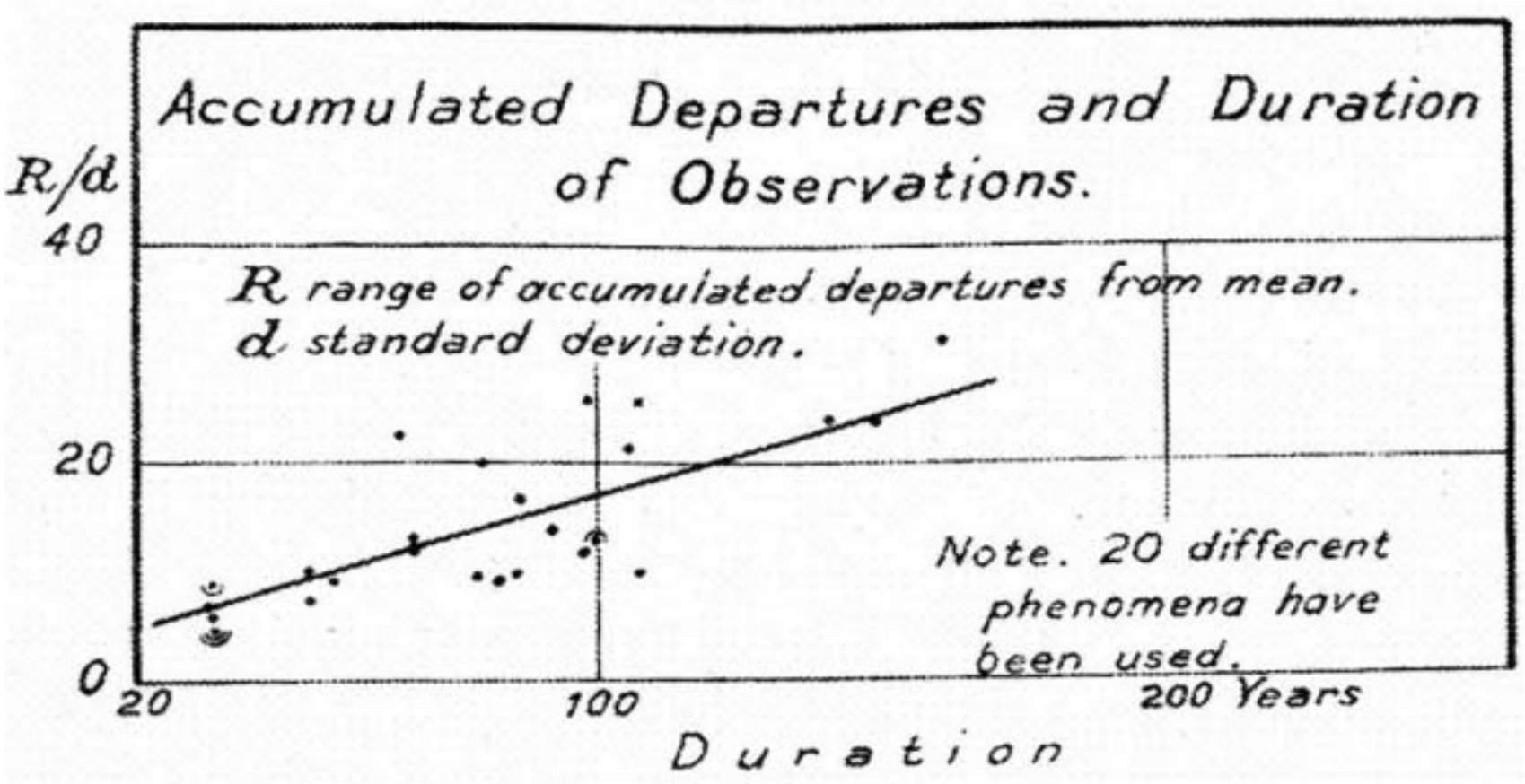
- Hurst travelled all over the basin, especially Sudan and East Africa
- He planned the Equatorial Nile Project
- This included reservoir storage in East African Lakes and the Jonglei Canal
- He also undertook research on long-term storage

RESEARCH ON RESERVOIR STORAGE

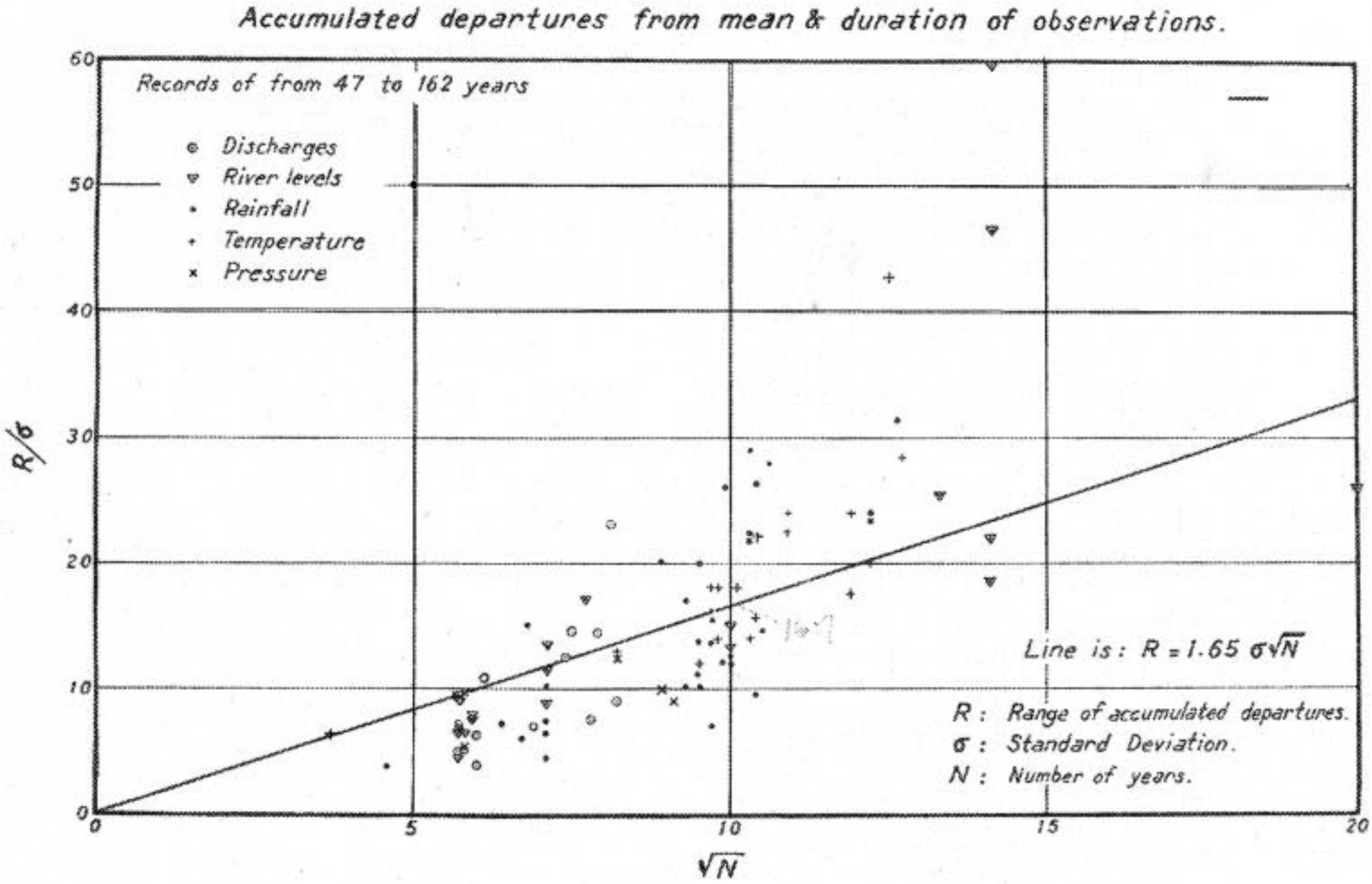
- Research began in 1936 before age of computers
- This research linked range of cumulative departures with duration
- This research compared ranges of natural data with random series
- Results were published in Egypt in *The Nile Basin* series


Accumulated Departures and Duration of Observations.
R/d
40
20
0
R range of accumulated departures from mean.
d standard deviation.
Note. 20 different phenomena have been used.
20
100
200 Years
Duration

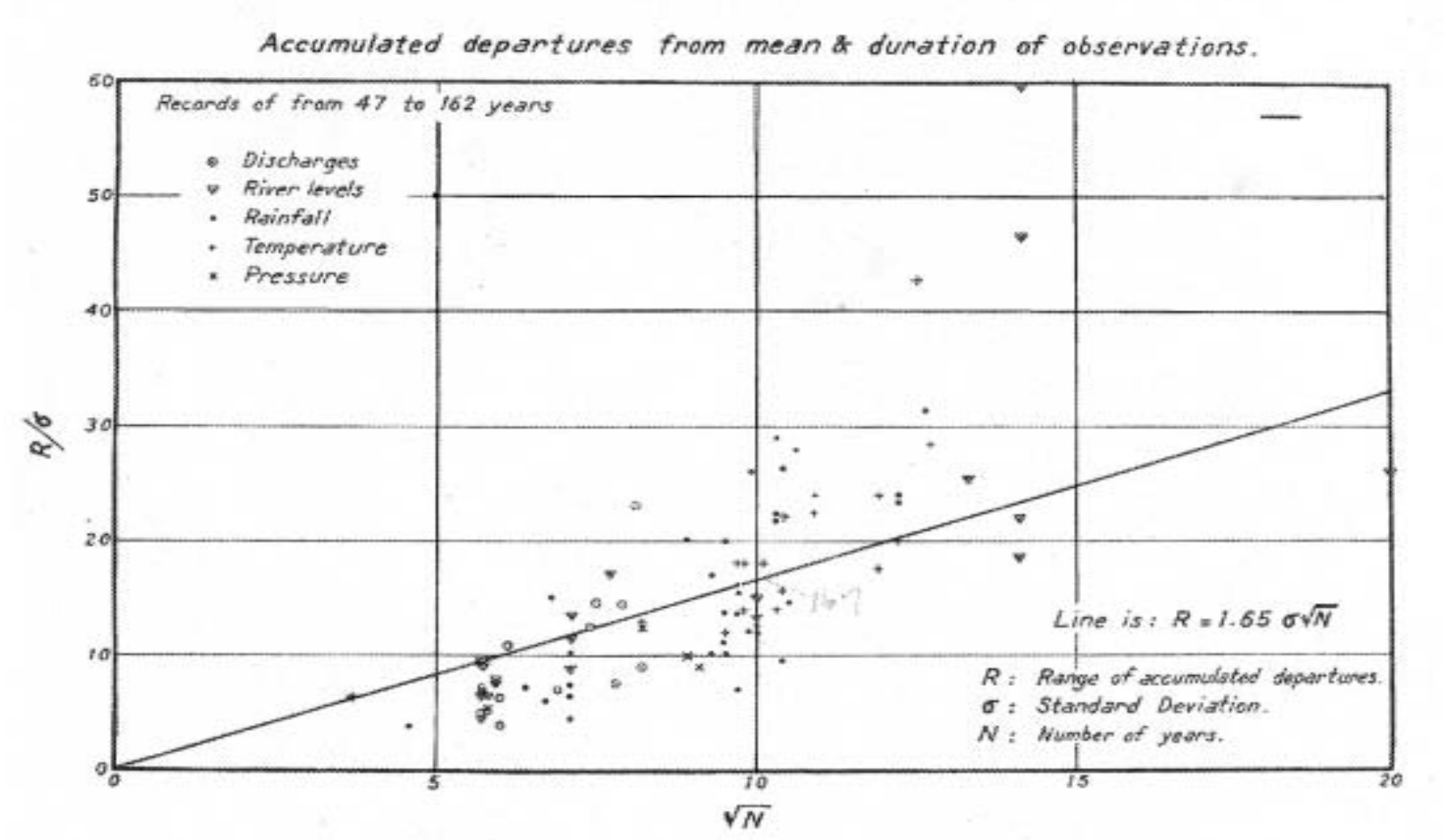
RESEARCH TO 1938



It includes river flows, rainfall, temperatures and pressures
20 different phenomena from different parts of the world
First diagram (1938) compares Range/Std devn (R/σ) with Duration (N)
He concludes that natural data cannot be treated as random

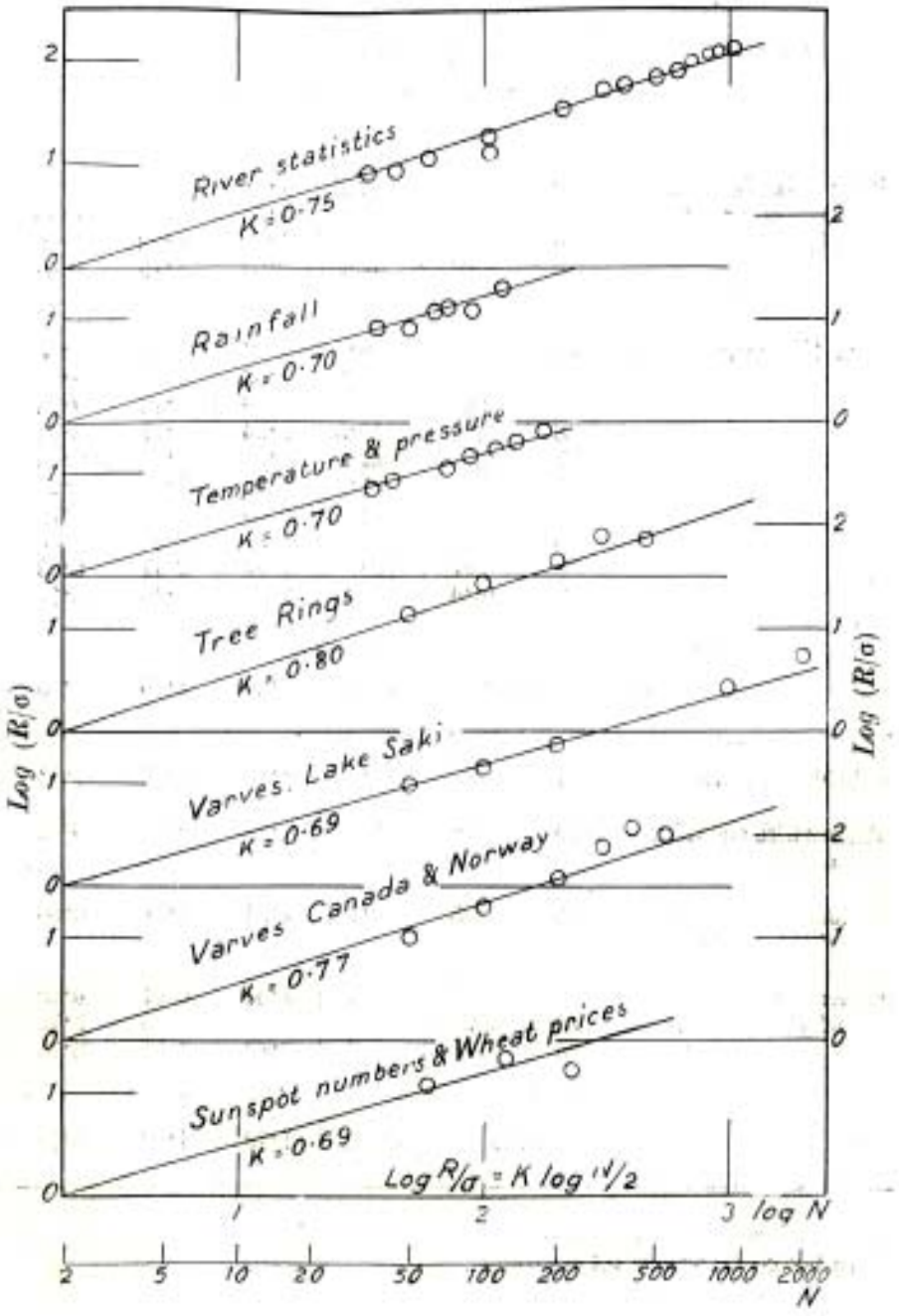

Accumulated departures from mean & duration of observations.
Records of from 47 to 162 years
Discharges
River levels
Rainfall
Temperature
Pressure
Line is : R = 1.65 σ√N
R : Range of accumulated departures.
σ : Standard Deviation.
N : Number of years.
R/σ
√N
0
5
10
15
20
30
40
50
60

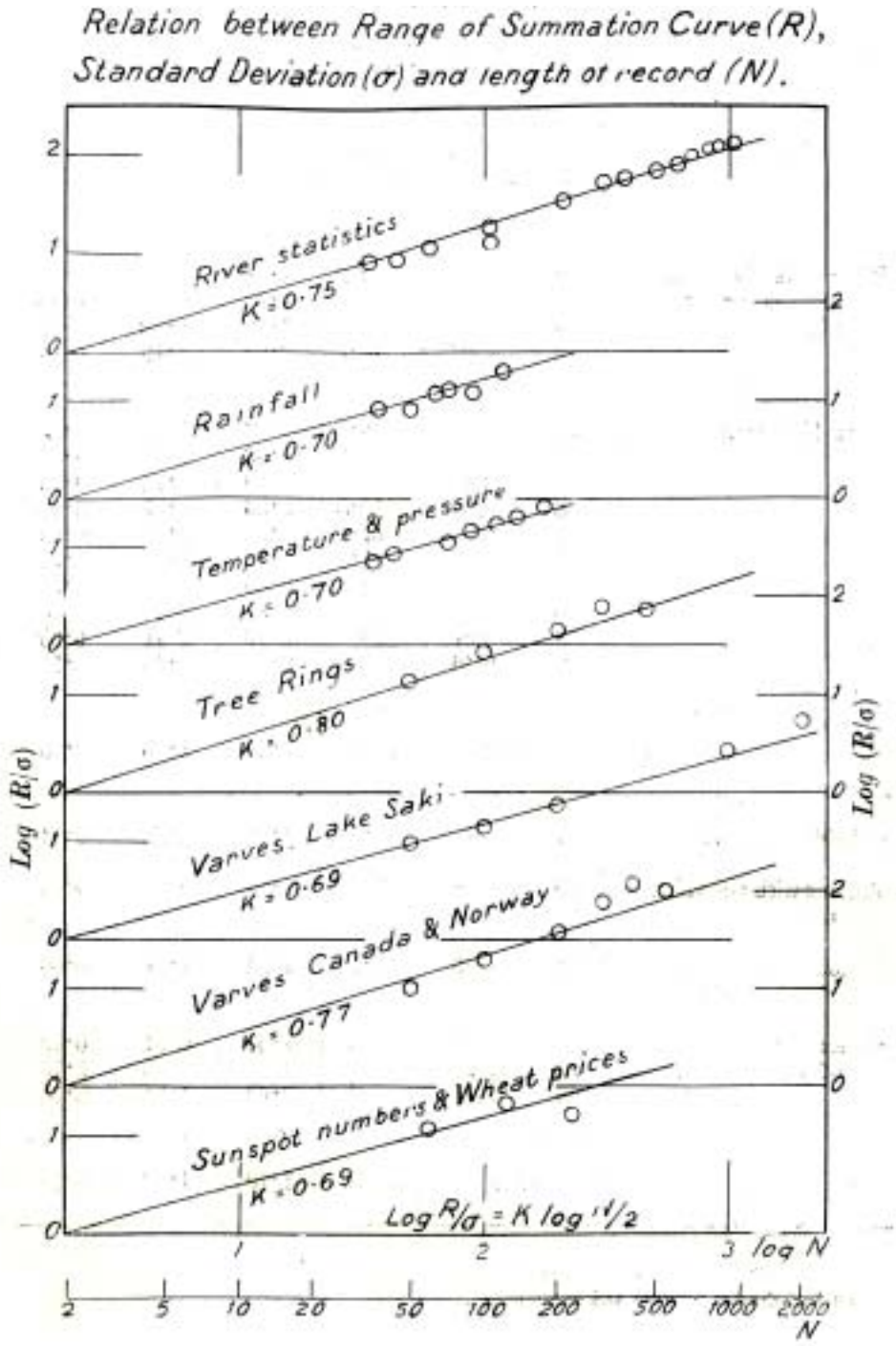
RESEARCH TO 1946



The second diagram (1946) uses 60 different phenomena
R/σ plotted against √N following random series
Tossing 10 coins 1000 times gave R/σ =1.25√N
Natural comparison gave rise to R/σ =1.65√N

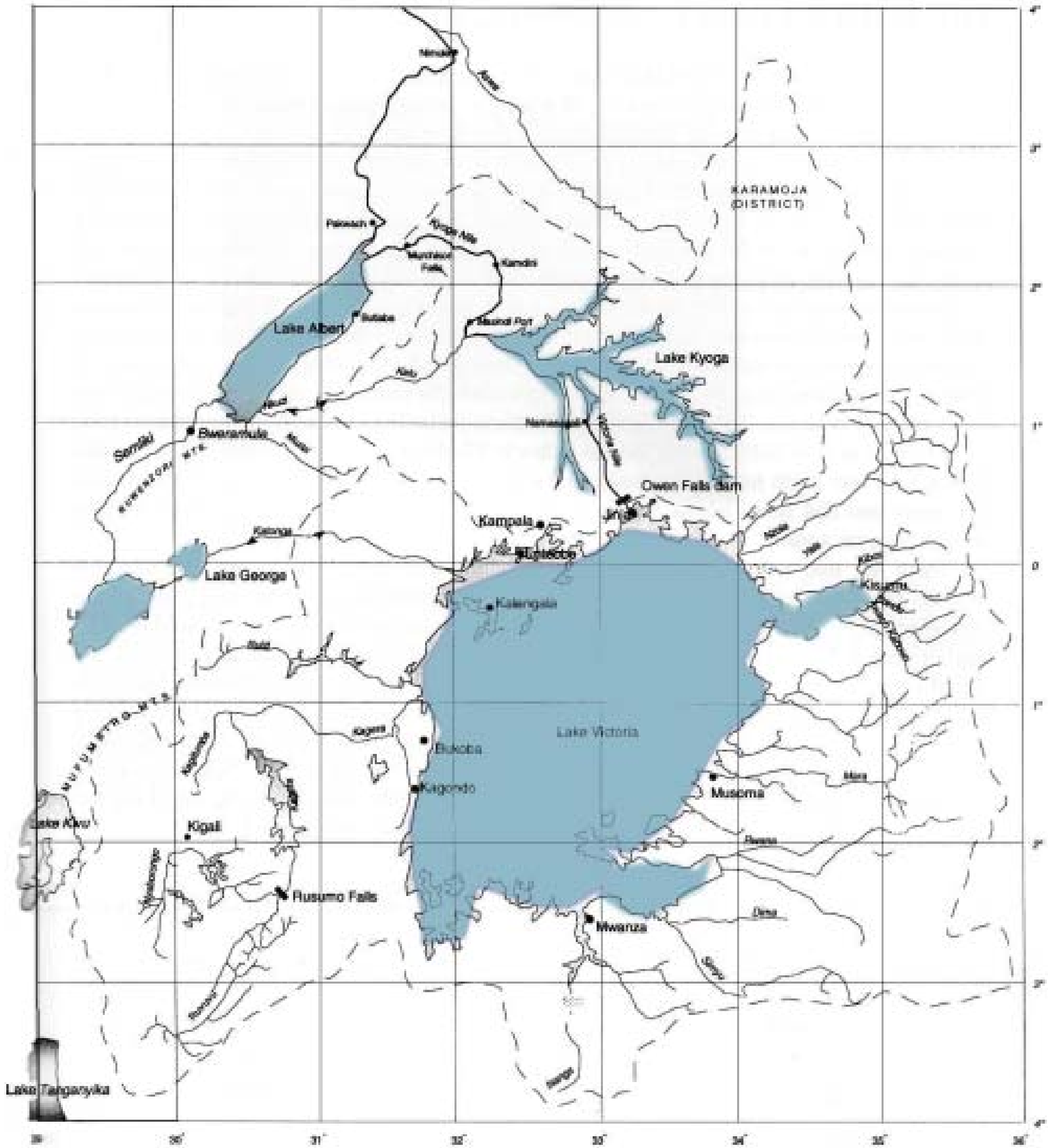
Relation between Range of Summation Curve (R), Standard Deviation (σ) and length of record (N).

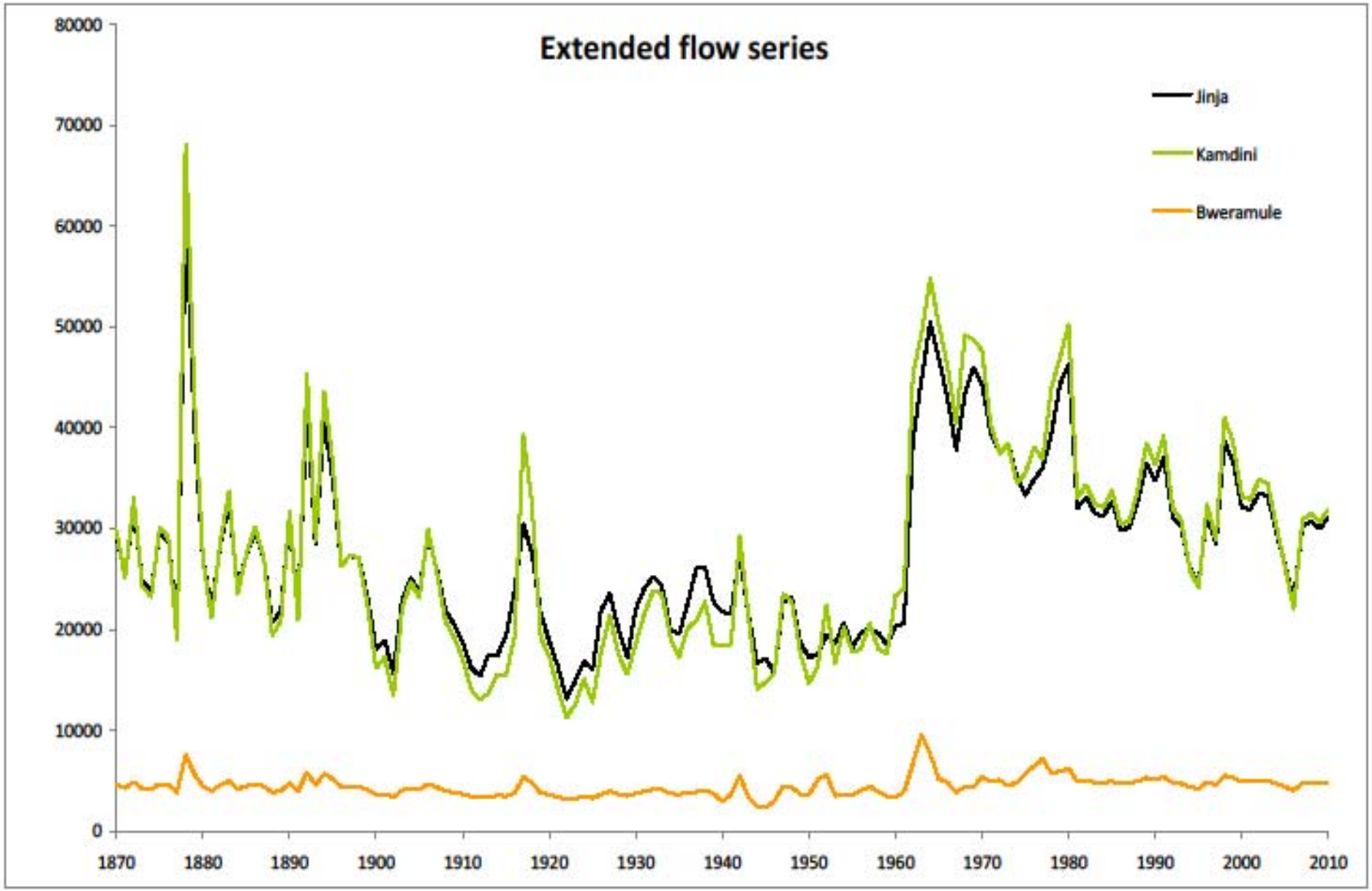


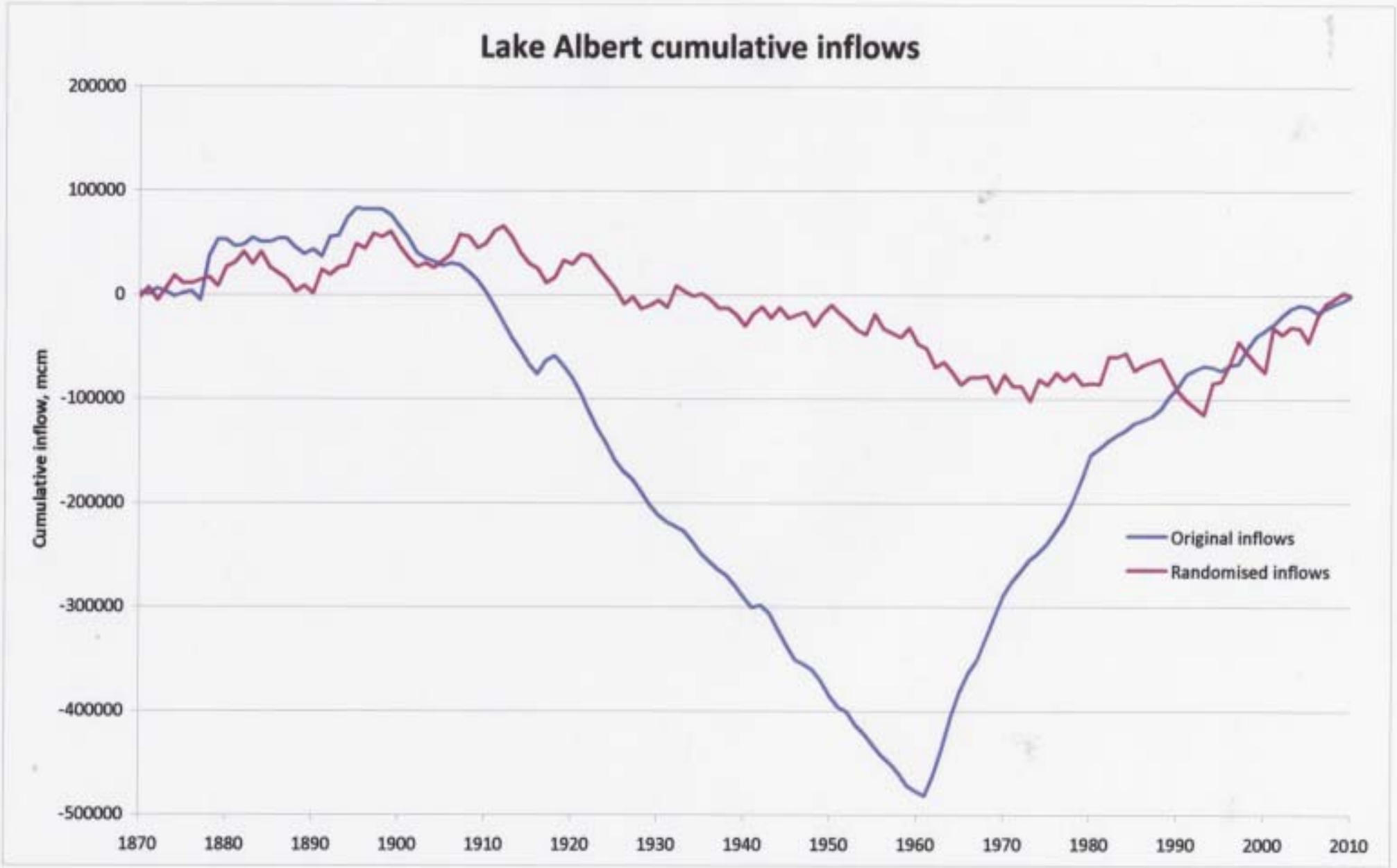


RESEARCH TO 1949

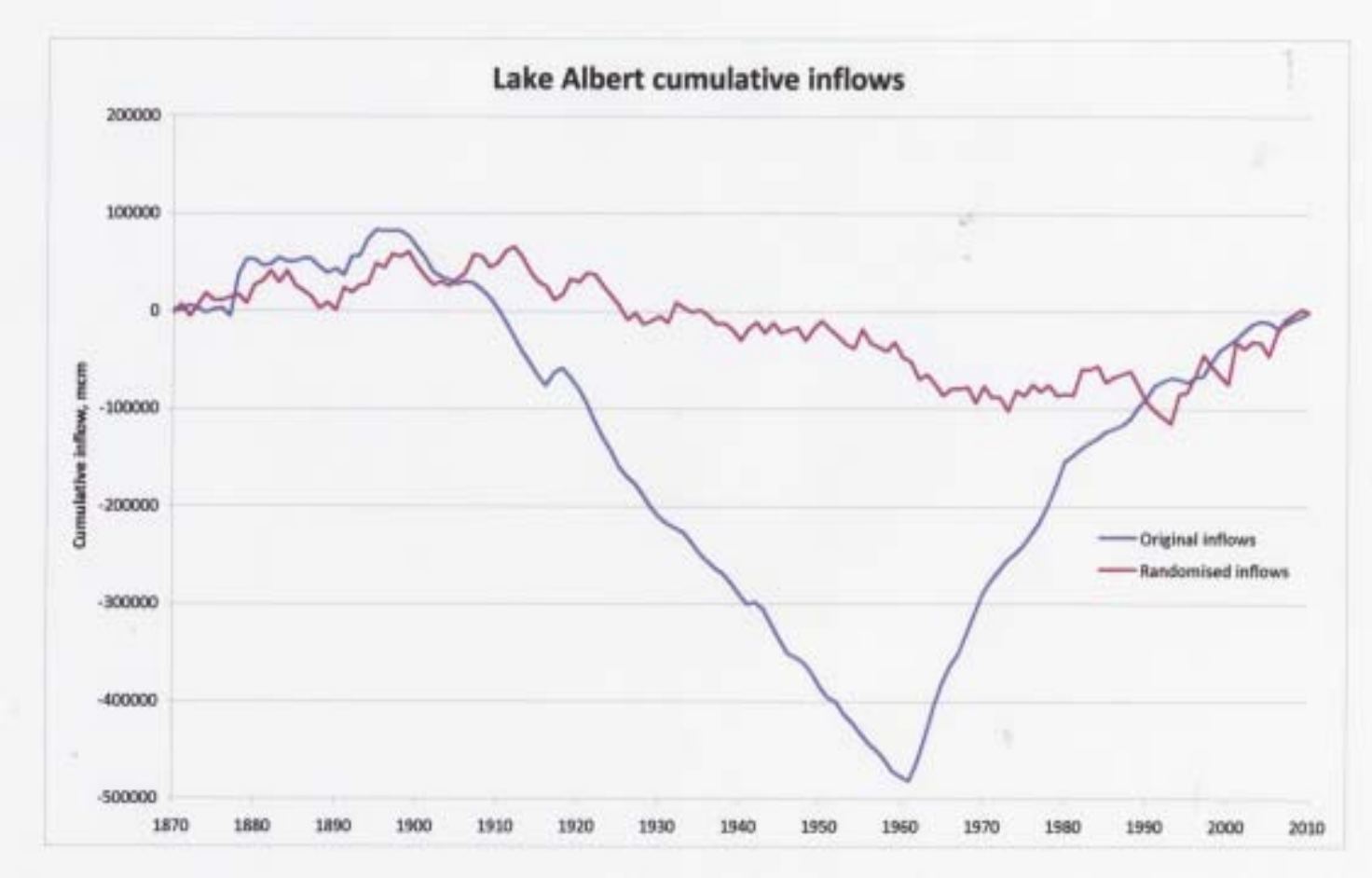
- By third diagram (1949), several longer series were included
- Nile flood series at Roda, tree rings and lake varves
- N values reach further right and form of relation clearer
- Values of log(R/σ) plotted against log N
- Relation log(R/σ) = K log(N/2) with K = 0.72


Nimule
KARAMOJA (DISTRICT)
Pakwach
Victoria Nile
Murchison Falls
Kamdini
Butiaba
Lake Albert
Masindi Port
Lake Kyoga
Bweramule
Semliki
RWENZORI MTS
Namasagali
Owen Falls dam
Jinja
Kampala
Entebbe
Lake George
Kalangala
Kisumu
Lake Victoria
Bukoba
Kagondo
Musoma
Mara
Lake Kivu
Kigali
Rusumo Falls
Mwanza
Lake Tanganyika
29°
30°
31°
32°
33°
34°
35°
36°
4°
3°
2°
1°
0°
1°
2°
3°
4°

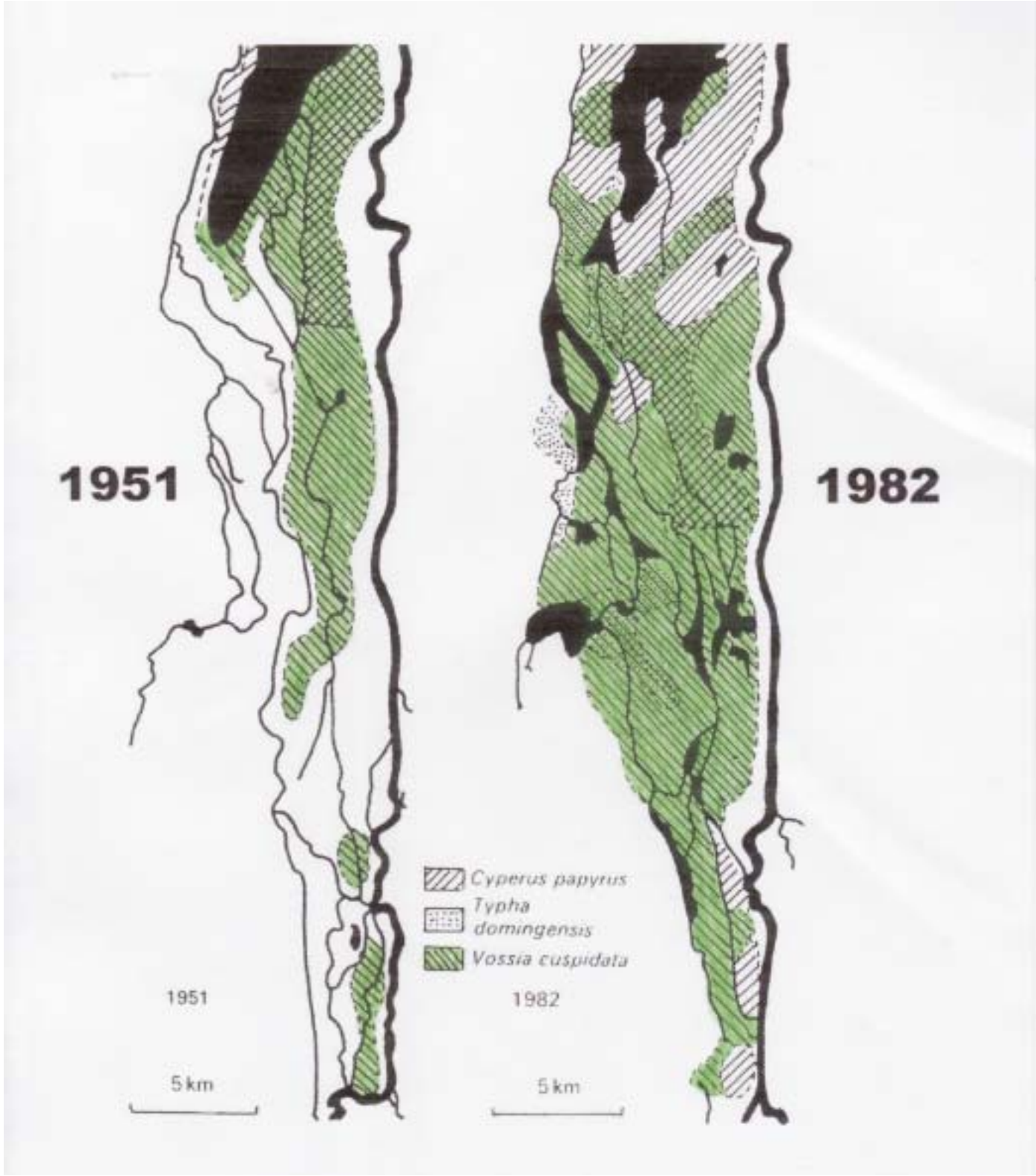

Extended flow series
Jinja
Kamdini
Bweramule
80000
70000
60000
50000
40000
30000
20000
10000
0
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010


Lake Albert cumulative inflows
Cumulative inflow, mcm
200000
100000
0
-100000
-200000
-300000
-400000
-500000
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Original inflows
Randomised inflows

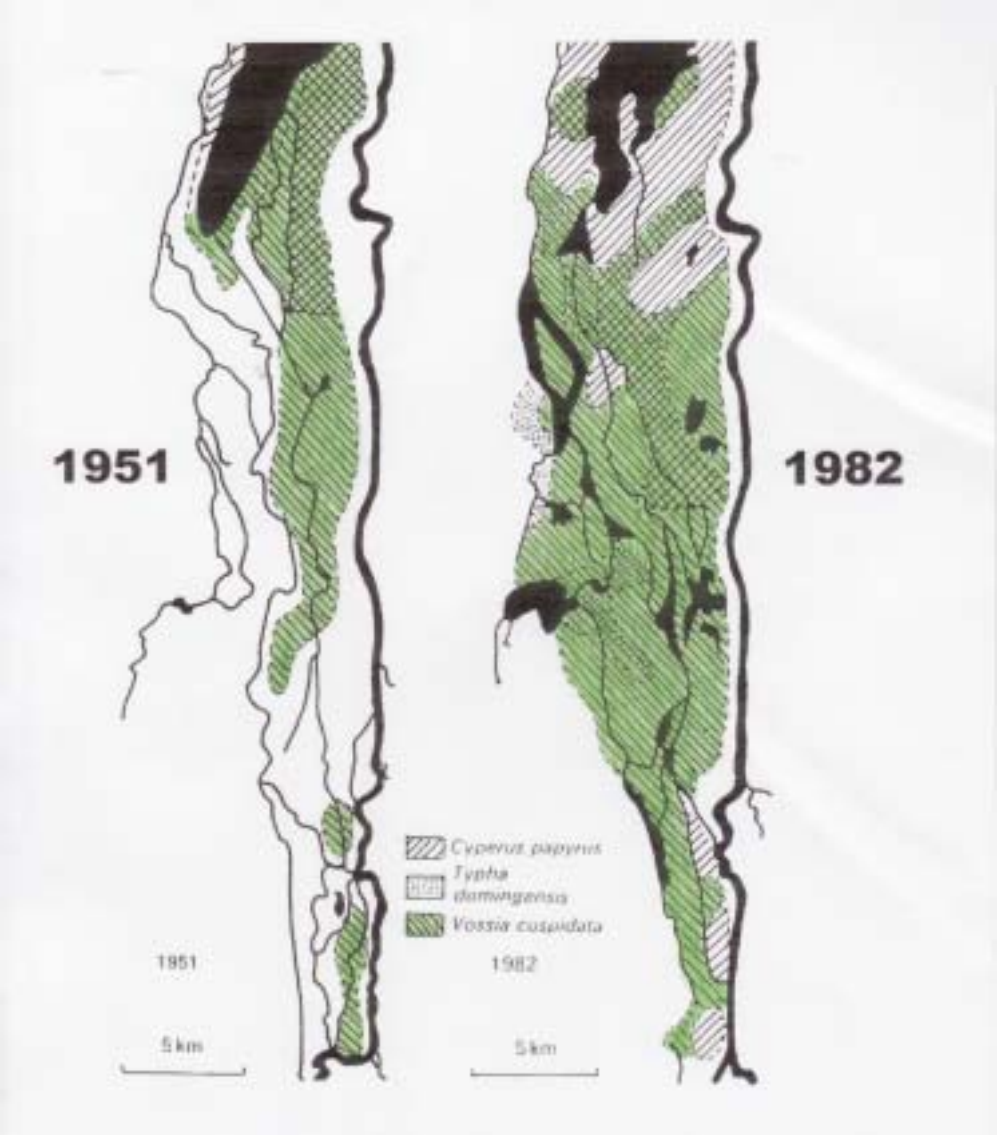
STUDY OF LAKE ALBERT RESERVOIR



Difference between natural and random series can be illustrated
Lake Albert reservoir site focus of Hurst's original research
Historic inflows to Lake Albert extended to 1870-2010
Ranges of historic and randomised inflows are compared


1951
1982
Cyperus papyrus
Typha domingensis
Vossia cuspidata
1951
1982
5 km
5 km

SUDD VEGETATION



- The dry season grazing in the Sudd is sensitive to inflow
- The reservoir operation would have reversed the natural flooding seasons
- The Jonglei Investigation Team concluded that this was unacceptable
- Attention turned to the Aswan High Dam

IMPLICATIONS OF HURST FOR WATER RESOURCES

- The Hurst phenomenon increases importance of overyear storage
- Mean runoff cannot be estimated precisely from 30 year record
- Flow records should be extended using rainfall or longer flow records
- Reservoir capacity cannot be estimated from simple statistics