Mausam, (1990), **41**, 4, 565-568

551.7.02 : 551.521.11

Correlation analysis between the sunspots and the *Nile* flood

M. A. MOSALLAM SHALTOUT

National Research Institute of Astronomy and Geophysics, Helwan-Cairo, Egypt

and

M. T. Y. TADROS

Faculty of Science, Physics Department, Mansoura University, Egypt.

(*Received 20 November* 1989)

सार — सूर्य धब्बा संख्या आर. जेड. के वार्षिक माध्य मान के काल क्रमों के मध्य क्रास संबंध का विश्लेषण निम्न के साथ किया गया है :

(क) 1748-1914 की अवधि के नील नदी में अधिकतम की बाढ़ के वार्षिक मान,

(ख) उसी अवधि के लिए नील नदी में अधिकतम बाढ़ और पुराने जल के अन्तर का वार्षिक मान।

आर जेड के वार्षिक माध्य मान और निम्नलिखित के साथ प्रत्यक्ष और क्रास सहसंबंध अन्तर किया गया है :

(अ) 1900-1959 की अवधि के लिए ईथोपियन उच्च भूमि के अदिस अबाबा पर मि० मी० में वर्षा का वार्षिक मान,

(ब) 1904-1957 की अवधि के लिए एलबर्ट झील (सफेद नील स्रातो में से एक) के अपवाह का वार्षिक मान, और

(स) 1870-1960 की अवधि के लिए 10^9 मी^{3} में असवान (मिश्र में) पर नील अपवाह के वार्षिक मान।

इनके परिणाम यह दर्शाते है कि सहसंबंध गुणांक क्षीण है। किन्तु सूर्य धब्बों के 11 वर्ष चक्र के क्रास सहसंबंध आवृति दर्शाते हैं।

ABSTRACT. The analysis of the cross-relation between the time series of the annual mean value of sunspot number *Rz* with :

(a) The annual value of the maximum *Nile* flood for the period (1748-1914),

(b) The annual value of the difference of the old water and maximum *Nile* flood for the same period are carried out.

Also, the direct and the cross-correlation between the annual mean value of *Rz* with the following have been done :

(a) The annual value of rainfall in mm on Addis Ababa at Ethiopian high lands for the period (1900-1959),

(b) The annual value of the discharge of Albert lake (one of the white *Nile* sources) for the period (1904-1957), and

(c) The annual value of the *Nile* discharge at Aswan (in Egypt) in 10^9 m^3, for the period (1870-1960).

The results indicate that the direct correlation coefficients are weak. But the cross-correlation show close to the eleven year cycle of the sunspots.

1. Introduction

Earlier investigations have shown that the correlation between sunspot number and the annual rainfall may be positive, negative or non-existent, depending on where the meteorological measurements are made (Herman and Goldberg 1978). Other indirect indicators of rainfall include water level in lakes and river flooding.

The correlation coefficient of the mean annual water level of the lake Victoria and sunspots number from 1880's to 1920's is +0.88 (Shaw 1928). This implies an excess of rainfall at sunspot maximum for the region of lake Victoria (2.0° S, 32.2° E) in Africa, in agreement with Clayton's distribution (Clayton 1923), showing excess rainfall in equatorial regions. But according to Bargman *et al.* (1965), the correlation broke down around 1930.

Beginning circa 1950, the water level has been negative correlation with sunspot number (Herman and Goldberg 1978). Also in the equatorial belt is the *Nile* river, which flows out of lake Victoria. The mean height of this river in Egypt for the year 1737-1908, almost two centuries was analyzed by Clayton (1923) in relation to sunspot activity. For his first group of data (1737-1800), he found maximum height about 1 year after sunspot maximum and minimum heights about 1 year before sunspot minimum.

In the second data set (1825-1908), the maximum river height lagged sunspot maximum by about 2 years. This variation again implies greater rainfall in the equatorial belt in years near solar maximum. A correlation of + 0.36 was found by Shaw (1928), between *Nile* flooding and sunspot number. Brooks (1926, 1949) has drawn attention to the possible relation of the secular variation of *Nile* levels to solar activity.

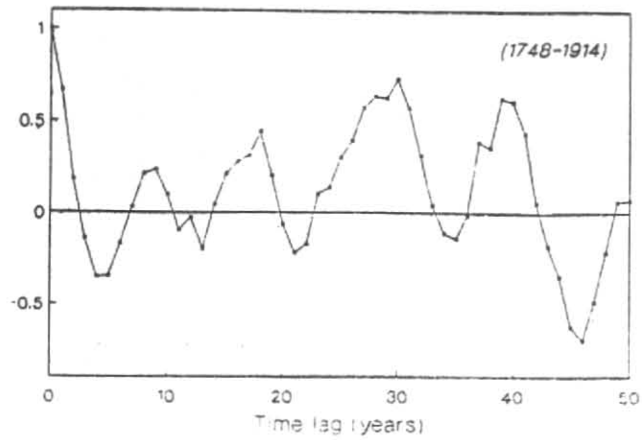

Fig. 1. Cross-correlation of max. *Nile* flood and sunspot

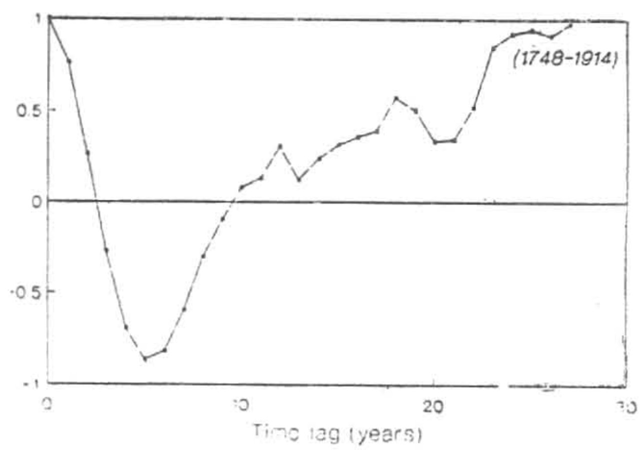

Fig. 2. Cross-correlation of difference *Nile* flood and sunspot

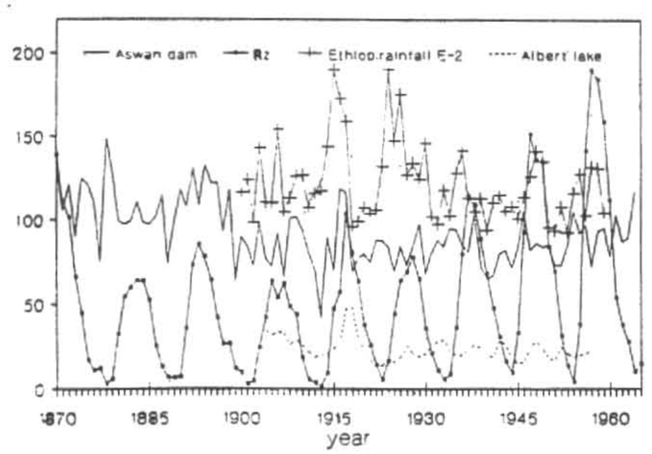

Fig. 3. Time series data

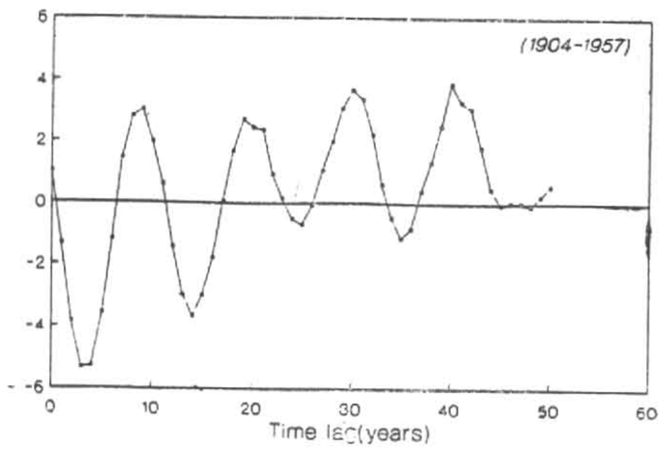

Fig. 4. Cross-correlation of R_z and Ethiopian rainfall

Verner (1927), assuming that *Nile* level variations are related to solar activity. Letfus (1986) found that, secular variations of the river *Nile* levels, regularly measured from the 7th to 15th century A. D., clearly correlate with the solar variations, which suggests evidence for solar influence on the climatic changes in the east African tropics. Hameed (1984) found a periodicity of length 19-year in the *Nile* flood data, the periodicity is attributed to the lunar tide of 18.6 years, which has been previously detected in precipitation records from North and South America, India and China.

Mosalam Shaltout and Tadros (1990) from long time series data of the *Nile* flood cover the period from the 5th to 17th century, and by using power spectra analysis, they found that, there are similarity between the long term periodicity in the solar activity and the *Nile* flood data.

The purpose of this research is to find the degree of the correlation between the sunspots activity and the level of the *Nile* flood, from using direct and cross-correlation analysis.

2. Data

2.1. *Data of the river Nile floods*

Chronical records of yearly observations of the *Nile* level exist from 622 A. D. Low *Nile* level were recorded around 30 June, so called old water, which represent approximately the minimum levles of the river throughout the year and maximum flood values regardless of the series of the calendar data. The continuous series of *Nile* records continuous until 1470 A. D., after which there are great gaps in the records, and the uninterrupted series continues again from 1838 A. D.

All records from the beginning to 1921 A. D. were collected and published by Toussoun (1925), and Sami (1916).

A detailed analysis of all accessible data was made later by Popper (1951). The used data in the present work about the river *Nile* floods are available from "The Nile Calendar" by Sami (1916).

2.2. *Data of the sunspot number R_z*

The sunspot number for the period (1610-1960) are published in "The *sunspot activity in the years* 1610-1960" by Professor M. Waldmeier, copy right 1961, Swiss Federal observatory, Zurich, Switzerland.

In 1987, Waldmeier's text has been revised and edited by John A. Mckinnon and published in new text of the same "*Sunspot Numbers* : (1610-1985)" as Report No. UAG-95, from World Data Center A for Solar-Terrestrial Physics, Boulder, Colorado, USA.

2.3. *The other data*

This contain three types of data as follows :

(a) Tha annual values of rainfall in mm on Addis Ababa at Ethiopian high lands for the period (1900-1959), from (Griffith 1927).

(b) The annual value of the discharge of the Albert lake (One of the *White Nile* sources) for the period (1904-1957), from (Hurst *et al.* 1966).

(c) The annual value of the *Nile* discharge at Aswan (in Egypt) in 10^9 m^3, for the period (1870-1960), from (Hurst *et al.* 1966).

3. Method of computation

Normalized cross-correlation analysis $C_{12}(T)/C_{12}(O)$ are applied for the sunspot number and *Nile* flood for long period using the following formula (Markus 1974) :

$$C_{12}(T) = \frac{1}{N-T} \sum_{t=1}^{N-T} [X(t) - \bar{X}] . [Y(t+T) - \bar{Y}] \quad (1)$$

where ,

N is the total number of data points,

T is the lag number (T=0, 1, 2........Tm),

Tm is the maximum lag,

$X(t)$ and $Y(t)$ are the observed data to be cross-correlation, $\bar{X}$ and $\bar{Y}$ are their average values.

For the direct linear correlation, we used the well-known formula of the case of two variables X and Y (Gupta and Ratana 1973) as follows :

$$r = \frac{\Sigma XY - \Sigma X \Sigma Y/N}{[\Sigma X^2 - (\Sigma X)^2/N]^{1/2} . [\Sigma Y^2 - (\Sigma Y)^2/N]^{1/2}} \quad (2)$$

where,

X is deviations or step deviations of X from its assumed mean,

Y is deviations or step deviations of Y from its assumed mean

N is number of pairs of values, *i. e.*, number of items of each variable.

4. Results and discussion

The analysis of the cross-correlation between the time series of the annual mean value of sunspot number R_z with :

(a) The annual value of the maximum *Nile* flood for the period (1748-1914).

(b) The annual value of the difference of the old water and maximum *Nile* flood for the period (1748-1914).

The results are shown in Figs. 1 & 2 for (a) and (b) respectively. From the figures, we can notice the following :

(1) The first point (lag=0), indicate correlation between R_z and maximum *Nile* flood, and with the difference between the old water and maximum *Nile* flood.

(2) There is periodicity of about 11-year or its multiples in the two figures. It is more clear in Fig. 1.

The time series of R_z, rainfall in Ethiopian high lands, Albert lake discharge, and *Nile* discharge at Aswan, can be shown in Fig. 3. From Fig. 3 we can notice the following :

(1) There is a remarkable similarity between the time series of R_z and the *Nile* discharge at Aswan for the period (1870-1916). After 1916 discharge of *Nile* at Aswan is controlled by Aswan dam.

(2) There is a remarkable similarity between the time series of R_z and rainfall on Addis Ababa, can be shown in the following table:

Years of min solar activity	*Years of max solar activity*	*Years of max rainfall*
1901	1905	*1906
1913	1917	**1915
1923	1928	**1924-26
1933	1937	*1936
1944	1947	*1948
1954	1957	*1957

For six peaks in the time series of rainfall, we notice that, four peaks (*) close to the maximum of R_z, while two peaks (**) are in the midway between the maximum and minimum of R_z.

(3) The time series of Albert lake discharge do not show a clear similarity with that of R_z. It is possible, due to the storage mechanism of the lake, Hurst (1955).

The correlation coefficient between the relative sunspot number R_z with :

(a) The rainfall on Addis Ababa is 0.090.

(b) The discharge of Albert lake is 0.219.

(c) The discharge of *Nile* at Aswan is 0.108.

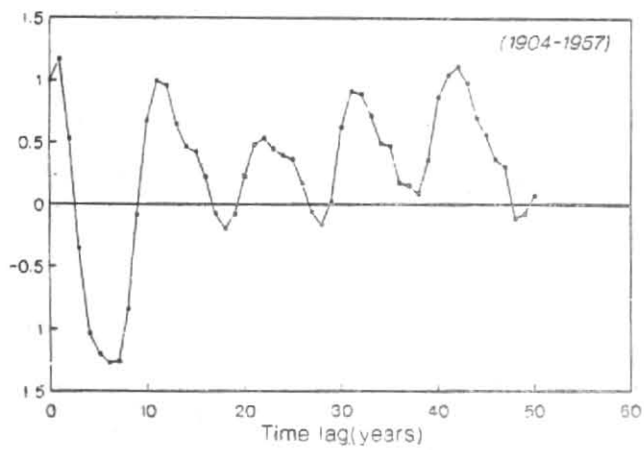

Fig. 5. Cross-correlation of R_z and Albert lake discharge

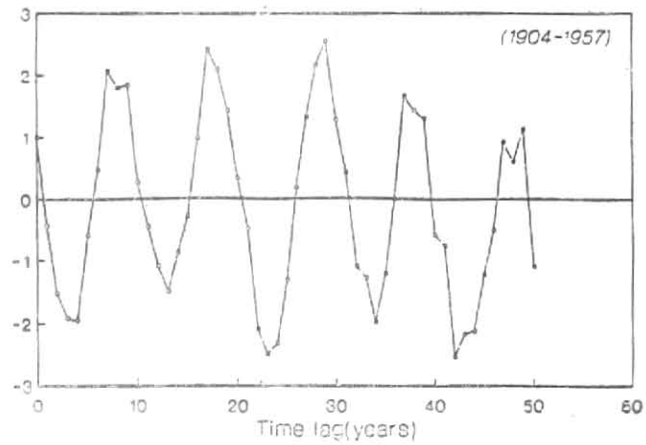

Fig. 6. Cross-correlation of R_z and Aswan dam discharge.

The direct correlation coefficients are weak. But the cross-correlation analysis between R_z and rainfall on Addis Ababa, discharge of Albert lake and discharge of *Nile* at Aswan can be seen in Figs. 4-6 respectively. From these figures, one can notice the periodicity of the eleven year cycle of the solar activity.

5. Conclusion

From our present results and discussion, we confirm our previous conclusions in an earlier study (Mosalam Shaltout and Tadros 1990) as follows:

(a) The periodicities in the *Nile* flood are correlated with the 11-year cycle of solar activity or its multiplies.

(b) Solar activity affects the solar constant. Consequently, the solar constant changes the weather and climate (or at least forcing the change). Hence, fluctuations in the rainfall of the tropic regions occur. The oscillations in the *Nile* flood is an indirect evidence for the variability of the rainfall in the tropic of East Africa.

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