



Case report

Statistical study of the solar eclipses over Egypt during 20 centuries (1–2000)

H.I. Abdel-Rahman^{a,b}, B.A. Marzouk^{a,c,*}^a National Research Institute of Astronomy and Geophysics (NRIAG), 11421 Helwan, Cairo, Egypt^b Department of Mathematics, Faculty of Science and Arts, Shaqraa University, Shaqraa, Saudi Arabia^c Doctor of Astronomy, Qatar Calendar House, Doha, Qatar

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ABSTRACT

During solar eclipses the scientists can be observe and studying the solar atmosphere. The stratified structures of the solar atmosphere are mainly the photosphere, the chromosphere and the corona.

In this work we used the Least Square (LS) method to investigate the statistical study of the solar eclipses during 20 centuries (1–2000). We found the formula for total number of every types of solar eclipse. We get the frequency distribution of all eclipses for 20 centuries over Egypt; the percentage ratio for partial solar eclipse is 43.2%, while the percentage ratio for the annular solar eclipse is 30.1%, and the percentage ratio for total and hybrid solar eclipses are 22.3% and 4.4% respectively.

The General Linear Trend formula for predicting the future values for every types of solar eclipse was obtained and determined during next 500 years (2001–2500). We compare our results with calculated once by NASA for each types of solar eclipse. Our results are in a good agreement with that published by NASA.

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1. Introduction

At any given location, total eclipses will only recur on average every 375 years and are thus extremely rare events.

Eclipse events are highly predictable, given our knowledge of the mathematics of celestial mechanics, but this advantage may not have been enjoyed by the ancient Egyptians. Solar and lunar eclipses occur in regular cycles, known as the “Saros”, a fact that was well known in antiquity (Neugebauer, 1957).

Apparently, when an eclipse terrified the soldiers of Alexander who were fighting the Persians under Darius, appeal was made to the explanations of an Egyptian priest to calm the panic that overcame the troops (Sauneron, 2000).

Foley (1989) used a statistical study to investigation the solar eclipse records from 26 Dynastic Histories of China, from 204 B. C. - 1621 A.D., and the Korean records from 1009–1621 A.D., and found the solar eclipse records are interesting and tell a great deal about the Chinese and Korean approach to astronomy in the pre-telescopic era. The eclipse efficiency can act as a guide to the quality of their astronomical records as a whole. The sunspot records are mainly affected by the solar activity variations but the observing efficiency plays a significant role when the solar activity variations are stable {neither at a maximum nor a minimum nor fluctuating wildly}.

The history books of East Asia about Astronomical phenomena have the more records of the solar eclipse frequently than any other ones. It is because traditionally, the solar eclipse meant the fate of dynasty and the king's rule (Youn Sook and Yong Sam, 2004).

Han and Qiao (2009) studied the perception, observations and recording of solar and lunar eclipses in the ancient Chinese astronomers. They found that the ancient Chinese astronomers used the solar and lunar eclipses to assess and improve calendars, so they carefully observed and studied the movement of the celestial body in the solar system as well as the theory of solar and lunar eclipses.

Marzouk et al. (2016) investigated the Solar Eclipses During Four Centuries (1601–2000) and found that the percentage ratio

* Corresponding author.

E-mail addresses: helal_ismail@yahoo.com (H.I. Abdel-Rahman), bmarzoke@yahoo.com (B.A. Marzouk).

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for partial solar eclipse is 35.707%, while the percentage ratio for the annular solar eclipse is 31.166%, and the percentage ratio for total and hybrid solar eclipses are 26.522% and 6.605% respectively. And found a new formula for predicting the future values of all types of the solar eclipse types (partial, annular, total and hybrid).

In the present paper, we used the solar eclipses data occurrence over Egypt from NASA solar eclipse atlas. We applied the Least Squares (LS) method to find the general trend for each types solar eclipse occurrence over Egypt during 20 centuries (1–2000), the frequency distributions of each type of solar eclipses over Egypt are obtained. Then we calculate the forecasting of the future eclipses over Egypt for all types of solar eclipse during 5 centuries (2001–2500), and compared with published by NASA website.

2. Data used and method of analysis

We selected the path of every solar eclipse types (Annular, Partial, Total and Hybrid) data occurrence over Egypt from the NASA solar eclipse atlas at website: "<http://eclipse.gsfc.nasa.gov/SEatlas/SEatlas.html#2CE>" to find the formula for total number of every types of solar eclipse, this site contain the solar and lunar eclipses path for the past and the future.

We used the Least Squares (LS) method to find the general trend, which we used the time as "Independent Variable" and find series for all eclipse number, and each types of solar eclipse.

The general linear trend equation is:

$$\hat{y} = \hat{a} + \hat{b}x \quad (1)$$

where \hat{a} is the cut distance from horizontal axis, \hat{b} is the slope, and \hat{y} is the "the estimated value for phenomena trend", x is the time (which $x = 1$ for first series, $x = 2$ for second series...etc., every series = 100 years). The first from 1–100, the 2nd from 101 to 200, ..., and so on.

If we apply the Least Squares (LS) method in equation (1) we can get to:

$$\hat{b} = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} \quad (2)$$

$$\hat{a} = \bar{y} - \hat{b}x \quad (3)$$

Table 1

The frequency distribution and percentage ratio of Annular eclipse for 20 centuries (1–2000).

Centuries	Annular frequency	Percentage ratio (%)
1–100	5	8.06
101–200	2	3.23
201–300	2	3.23
301–400	3	4.84
401–500	2	3.23
501–600	5	8.06
601–700	4	6.45
701–800	0	0
801–900	4	6.45
901–1000	2	3.23
1001–1100	5	8.06
1101–1200	5	8.06
1201–1300	4	6.45
1301–1400	4	6.45
1401–1500	4	6.45
1501–1600	0	0
1601–1700	2	3.23
1701–1800	2	3.23
1801–1900	4	6.45
1901–2000	3	4.84
Sum	62	100

From Eqs. (2) and (3) we can find the estimation values for \hat{a} , \hat{b} , then substitute in equation (1) to get the future values for every type of solar eclipses.

3. Results and discussions

As we showed, we used the Least Squares (LS) method to find the general trend; before we apply this method we calculated the frequency distribution of all types of solar eclipse over Egypt during 20 centuries (1–2000).

Table 1 shows the frequency distribution of Annular eclipse for twenty centuries, while Table 2 shows the frequency distribution of total eclipse for twenty centuries, the frequency distribution of hybrid eclipse for twenty centuries shown in Table 3, the frequency distribution of partial eclipse for twenty centuries shown in Table 4,

Table 2

The frequency distribution and percentage ratio of total eclipse for 20 centuries (1–2000).

Centuries	Total frequency	Percentage ratio (%)
1–100	2	4.35
101–200	2	4.35
201–300	1	2.17
301–400	3	6.52
401–500	3	6.52
501–600	2	4.35
601–700	5	10.87
701–800	1	2.17
801–900	1	2.17
901–1000	2	4.35
1001–1100	1	2.17
1101–1200	5	10.87
1201–1300	3	6.52
1301–1400	2	4.35
1401–1500	2	4.35
1501–1600	3	6.52
1601–1700	0	0
1701–1800	2	4.35
1801–1900	5	10.87
1901–2000	1	2.17
Sum	46	100

Table 3

The frequency distribution and percentage ratio of hybrids eclipse for 20 centuries (1–2000).

Centuries	Hybrids frequency	Percentage ratio (%)
1–100	2	22.22
101–200	0	0
201–300	0	0
301–400	0	0
401–500	0	0
501–600	0	0
601–700	0	0
701–800	0	0
801–900	0	0
901–1000	0	0
1001–1100	1	11.11
1101–1200	0	0
1201–1300	0	0
1301–1400	2	22.22
1401–1500	0	0
1501–1600	1	11.11
1601–1700	1	11.11
1701–1800	2	22.22
1801–1900	0	0
1901–2000	0	0
Sum	9	100

Table 4

The frequency distribution and percentage ratio of partial eclipse for 20 centuries (1–2000).

Centuries	Partial frequency	Percentage ratio (%)
1–100	5	5.62
101–200	5	5.62
201–300	5	5.62
301–400	7	7.87
401–500	3	3.37
501–600	3	3.37
601–700	2	2.25
701–800	4	4.49
801–900	8	9
901–1000	5	5.62
1001–1100	3	3.37
1101–1200	3	3.37
1201–1300	2	2.25
1301–1400	7	7.87
1401–1500	6	6.7
1501–1600	5	5.62
1601–1700	5	5.62
1701–1800	2	2.25
1801–1900	1	1.1
1901–2000	8	9
Sum	89	100

Table 5

The frequency distribution of all eclipse for 20 centuries in Egypt.

Type of eclipse	Frequencies	Percentage ratio (%)
Partial	89	43.2
Annular	62	30.1
Total	46	22.3
Hybrids	9	4.4
SUM	206	100

and finally the frequency distribution of all eclipse for twenty centuries shown in Table 5.

4. The forecasting of future eclipses

After we apply the least squares method in Eq. (1), and find the estimation values for \hat{a} , \hat{b} and substitute in equation (1), we can find the future values for every type of solar eclipse as shown following:

4.1. The forecasting of future annular eclipse

The model for forecasting the annular eclipse is:

$$L_{\text{Egypt}} = 3.274 - 0.017 x$$

where L_{Egypt} and x are the dependent and independent variables respectively, $x = 21, 22, \dots$ and $\delta(L_{\text{Egypt}}) = \pm 0.74$, where $\delta(L_{\text{Egypt}})$ is the error propagation in the model.

Table 6

The comparison between our results and NASA results for one century.

Date	Annular		Total		Hybrid		Partial	
	Our results $\delta(L_{\text{Eg}}) = \pm 0.74$	NASA	Our results $\delta(T_{\text{Eg}}) = \pm 0.677$	NASA	Our results $\delta(H_{\text{Eg}}) = \pm 0.357$	NASA	Our results $\delta(P_{\text{Eg}}) = \pm 0.987$	NASA
2001–20100	3	2	2	5	1	0	4	7
2101–2200	3	3	2	3	1	1	4	2
2201–2300	3	3	2	3	1	0	4	3
2301–2400	3	5	2	4	1	0	4	1
2401–2500	3	4	2	2	1	0	4	4
Total	15	17	10	17	5	1	20	17

$\delta(L_{\text{Eg}})$ is the error propagation in the model for Annular eclipse type, $\delta(T_{\text{Eg}})$ is the error propagation in the model for Total eclipse type, $\delta(H_{\text{Eg}})$ is the error propagation in the model for Hybrid eclipse type, $\delta(P_{\text{Eg}})$ is the error propagation in the model for Partial eclipse type.

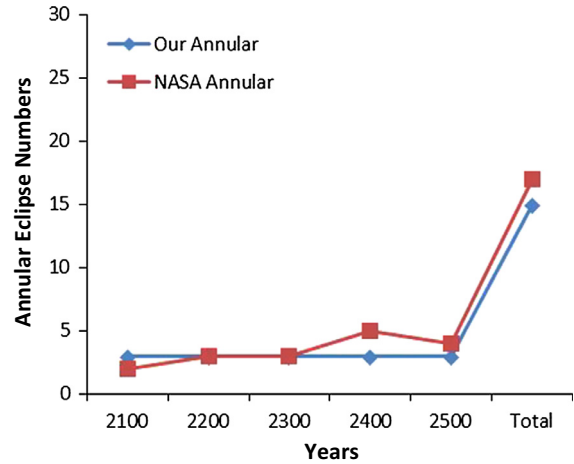


Fig. 1. Comparison between our results and NASA results for Annular eclipse.

$L_{2100} = 2.9-3$, $L_{2200} = 2.9-3$, $L_{2300} = 2.883-3$, $L_{2400} = 2.866-3$, $L_{2500} = 2.849-3$ (these values are approximate) and so on.

4.2. The forecasting of future total eclipse

The model for forecasting the total eclipse is:

$$T_{\text{Egypt}} = 2.237 + 0.006 x$$

If we substitute by $x = 21, 22, \dots$ (like the annular eclipse in Section 4.1) we can get:

$T_{2100} = 2.363-2$, $T_{2200} = 2.369-2$, $T_{2300} = 2.375-2$, $T_{2400} = 2.381-2$, $T_{2500} = 2.387-2$, \dots , and so on. $\delta(T_{\text{Egypt}}) = \pm 0.677$, where $\delta(T_{\text{Egypt}})$ is the error propagation in the model.

4.3. The forecasting of future hybrid eclipse

The model of forecasting for future hybrid eclipse is:

$$H_{\text{Egypt}} = 0.205 + 0.023 x$$

$H_{2100} = 0.688-1$, $H_{2200} = 0.711-1$, $H_{2300} = 0.734-1$, $H_{2400} = 0.757-1$, $H_{2500} = 0.78-1$, \dots , and so on. $\delta(H_{\text{Egypt}}) = \pm 0.357$, where $\delta(H_{\text{Egypt}})$ is the error propagation in the model.

4.4. The forecasting of future partial eclipse

The model is:

$$P_{\text{Egypt}} = 4.647 - 0.019 x$$

$P_{2100} = 4.25-4$, $P_{2200} = 4.23-4$, $P_{2300} = 4.21-4$, $P_{2400} = 4.19-4$, $P_{2500} = 4.17-4$, \dots , and so on. $\delta(P_{\text{Egypt}}) = \pm 0.987$, where $\delta(P_{\text{Egypt}})$ is the error propagation in the model.

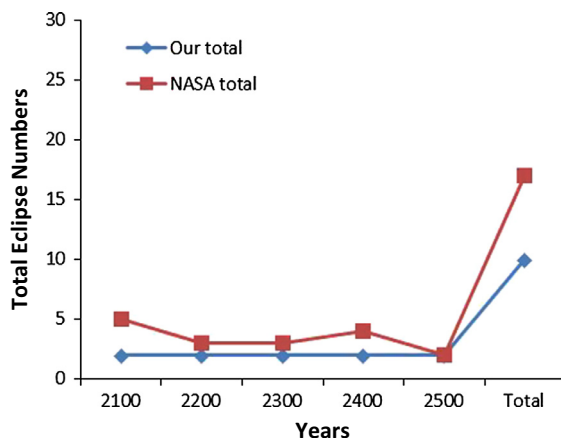


Fig. 2. Comparison between our results and NASA results for Total eclipse.

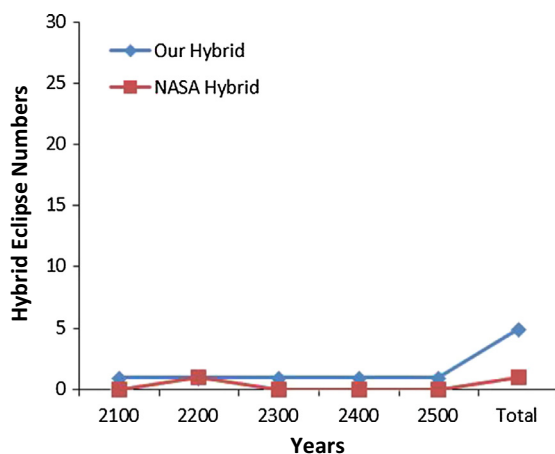


Fig. 3. Comparison between our results and NASA results for Hybrid eclipse.

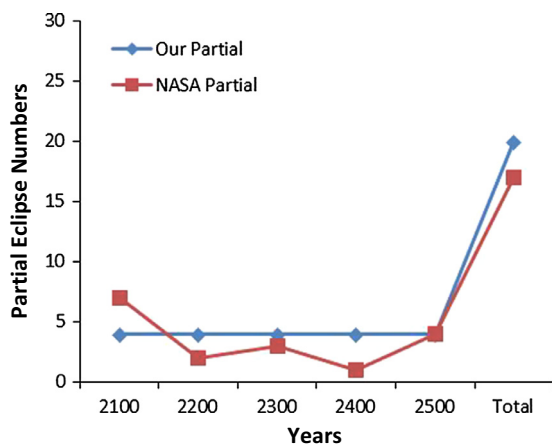


Fig. 4. Comparison between our results and NASA results for partial eclipse.

The comparison of our results for annular solar eclipse over Egypt during 500 years with published NASA results is shown in Fig. 1. The comparison of our results for total solar eclipse over Egypt during 500 years with published NASA results is shown in Fig. 2, while the comparison of our results for hybrid solar eclipse over Egypt during 500 years with published NASA results is shown in Fig. 3, finally the comparison of our results for partial solar eclipse over Egypt during 500 years with published NASA results is shown in Fig. 4.

From Figs. 1–4 we can note that the comparison of our results value for each type of solar eclipses during five centuries are in a good agreement with result values published by NASA solar eclipse atlas during future five centuries.

5. Conclusion

The frequency distributions of all solar eclipse types (Annular, Total, Partial and Hybrid) over Egypt during 20 centuries are calculated. And the frequency distribution of all eclipses for 20 centuries is obtained.

The Least Squares method gives us the general trend for each solar eclipse types over Egypt during 20 centuries (1–2000). We found that the frequency distribution of partial solar eclipse is 43.2%, while the frequency distribution of annular solar eclipse is 30.1% and the frequency distributions of total and hybrid solar eclipses are 22.3% and 4.4% respectively.

We have the forecasting of future values for every type of solar eclipses over Egypt during 5 centuries (2001–2500).

We compared our results with results Published by NASA during five centuries (2001–2500) over Egypt and we found the following:

- Our results for annular solar eclipse are in a good agreement with published NASA results and we have the same values with NASA for two centuries.
- Our results for total solar eclipses are in a good agreement with published NASA results and we have the same value with NASA for one century.
- For the Partial solar eclipse, our results are in a good coincident with NASA results.
- For the hybrid solar eclipse, there is a small difference with NASA results, this difference attributed to the rare occurrence of this type of the solar eclipses.

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Table 6 shows our result values for each type of solar eclipse (Partial, Annular, Total and Hybrid) over Egypt for future five centuries (2001–2500), and values published by NASA website for each types of solar eclipse over Egypt for future five centuries too.