STUDY OF THE DURATION OF THE SOLAR FLARE OF THE 23 AND 24 SOLAR CYCLES

ESTUDIO DE LA DURACIÓN DE LA FULGURACIÓN SOLAR DE LOS CICLOS 23 Y 24

Imad A. Hussain

Department of Physics, College of Science, University of Mosul, Nineveh, Mosul, Iraq.

(Received: 08/2022. Accepted: 10/2022)

Abstract

Studying solar flares and their characteristics is significant for understanding the dynamics of the sun. In this work, a new view for studying the duration time of solar flares is presented. Regarding the analysis of the duration time, one of the solar flares parameters is introduced for the solar cycles 23 and 24. This is done by ordering the duration time of solar flares into five groups of minutes (<30, 30-60, 60 90, 90-120, >120) and calculating the total annual duration time of solar flares for each group. The total annual duration time is also calculated for each class of solar flare classification (B, C, M, X). Their relationship with both F10.7 and Kp-index are also studied. We found that approximately 41 % of solar flares occur within 6-12 minutes for both solar cycles. Additionally, the total average of their duration time is 19.1 and 19.6 minutes, respectively. Also, the average duration time of the ascending phase is less than the descending phase of both solar cycles for all classes of solar flares, except for B-class, which is vice versa. The relationship between the duration time of solar flares with F10.7 is strong. In contrast, the relationship with the Earth's magnetic field is weak.

Keywords: duration of solar flares, solar activity, geomagnetic activity indices, solar radio flux.

dr.imad1972@uomosul.edu.iq
doi: https://doi.org./10.15446/mo.n66.104439

Resumen

El estudio de las fulguraciones solares y sus características es importante para entender la dinámica del sol. En este trabajo se presenta una nueva visión para el estudio del tiempo de duración de las fulguraciones solares. En cuanto al análisis del tiempo de duración, se introduce uno de los parámetros de las fulguraciones solares para los ciclos solares 23 y 24. Esto se hace ordenando el tiempo de duración de las fulguraciones solares en cinco grupos de minutos (<30, 30-60, 60-90, 90-120, >120) y calculando el tiempo de duración total anual de las fulguraciones solares para cada grupo. También se calcula el tiempo de duración total anual para cada clase de clasificación de las fulguraciones solares (B, C, M, X). También se estudia su relación con el F10.7 y el índice Kp. Encontramos que aproximadamente el 41 % de las fulguraciones solares se producen en 6-12 minutos en ambos ciclos solares. Además, la media total de su tiempo de duración es de 19,1 y 19,6 minutos, respectivamente. Asimismo, el tiempo medio de duración de la fase ascendente es menor que el de la fase descendente de ambos ciclos solares en todas las clases de fulguraciones solares, excepto para la clase B, donde es al contrario. La relación entre el tiempo de duración de las fulguraciones solares con F10.7 es fuerte. En cambio, la relación con el campo magnético de la Tierra es débil.

Palabras clave: duración de las fulguraciones solares, actividad solar, índices de actividad geomagnética, flujo de radio solar.

Introduction

Solar flares are among the most important phenomena on the surface of the sun. They are sudden emissions of energy spanning a wide range of the electromagnetic spectrum, where large flares increase energy production significantly, especially in X-rays, ultraviolet rays, and radio rays, while infrared and visible spectrum increase is less than 0.01 % [1]. Sometimes, these radiations and the accompanying particles are flowing at very high levels, several times higher than the flow of cosmic rays, thus simultaneously generating shock waves and magnetic disturbances, affecting the Earth's magnetosphere when the Earth is within the field of influence of the solar flare [2, 3].

Flares often form in the active regions, where they grow quickly and become more complex, and may also form during the dissolution phase of the active region. In general, flares are divided into two types: simple or compact, and two-ribbon flares. Simple flares form in pre-existing rings, have a smaller amount of energy ($\sim 10^{30}$ ergs), and have a shorter duration time ($\sim 10^{3}$ s), while two-ribbon flares are more energetic ($\sim 10^{32}$ ergs), have lengthier duration time ($\sim 10^{4}$ s), and are created from newer rings [1, 4]. Solar flares are divided into four stages: the precursor, the impulsive, the main, and the late stage. The precursor or "preflare" luster stage continues for a few minutes. This luster can be detected in the emissions of soft X-rays and extreme ultraviolet rays. The impulsive stage is part of the flash phase, in which all emissions reach their peak and continue from seconds to minutes. While the main stage, or gradual dissolution stage, is the main period during which the characteristic size of coronal structures can be determined. Finally, the late stage is dominated by soft X-ray emissions that cool the hot plasma, but some energy can be emitted [4–7].

X-rays are indicators of solar flares that have been observed by the GOES (Geostationary Operational Environmental Satellite) series satellites since 1976. The start time of the X-ray event is determined from the moment of the sharp increase in the X-ray flux, while the peak time of the X-ray event is determined at the moment of the X-ray flux peak. End time is the time during which the level of the dissolution of the flux decays into a region midway between the peak flux and the background level before the flare. Thus, the solar flare was classified according to the peak of the X-ray flux (in W/m^2) to A, B, C, M, X from 1 to 8 Angstroms of X-rays near Earth, where each category is 10 times stronger than the previous one and category X is the strongest [8]. The ultraviolet and X-ray fluxes resulting from solar flares significantly increase the ionization in the Earth's atmosphere, especially in the ionosphere.

All of these processes occur against the background of the turbulent interplanetary magnetic field. High-energy particles from flares and coronal mass ejections penetrate the Earth's upper atmosphere and lead to the destruction of the ozone layer. Shock waves and solar plasma emissions from large flares also cause violent disturbances in the Earth's magnetosphere – the magnetospheric storms. All these factors have different effects on near-Earth space, which in turn can affect radio communications, and cause malfunctions in navigation devices in aircraft, ships, and radar systems [9–13].

The solar radio flux, at a wavelength of 10.7 cm (2800 MHz), which is known as the F10.7 index (Solar Flux Unit (sfu) = 10^{-22}W m^{-2} Hz^{-1}), is used to indicate the amount of solar activity coming from the solar chromosphere and corona. It also tracks other important emissions that form in the same regions of the solar atmosphere, making the F10.7 index of great value in determining and predicting space weather. F10.7 correlates well with the number of sunspots as well as with the measurements of ultraviolet and visible radiation emitted by the sun. Several studies dealt with the relationship of the F10.7 index with solar activities [5, 14–16]. The index (K) was used for several decades to express the intensity of main geomagnetic turbulences resulting from the interaction of the solar wind with the magnetosphere. The value of the K index ranges from 0 to 9 and is dependent on the maximum magnetic field variation, on a quasi-logarithmic scale, for any given (national) observatory. The Planetary Index Kp is an average K index of selected ground-based magnetometers with global coverage. They were used to study the effect of solar phenomena on space weather [17, 18].

The study of solar flares and their characteristics is very important for understanding the dynamics of the sun and it is also important for knowing its impact on the Earth's atmosphere. The duration time of solar flares (DSF) is one of its parameters and has not been fully analyzed by the few researchers that dealt with it [9, 14, 18–20]. In this paper, we will study and analyze the solar flare duration time for solar cycles 23 and 24 and then the impact of the solar flare duration time on the Earth's atmosphere by measuring its relationship with the indicators (F10.7 and Kp).

Materials and methods

Data Sources

Daily data of Solar Soft X-Ray (SXR) flares used in this study has been downloaded from the archived folders from the GOES of the National Oceanic and Atmospheric Administration (NOAA) website [21] for solar cycles 23 and 24, covering the period from January 1996 to December 2019. The data was produced by X-ray Sensor (XRS) tool onboard the GOES satellites. Daily solar radio flux index (F10.7 cm) and geomagnetic (Kp index) data were taken from the international space-related research centers OMNI2 (Operating Mission as Nodes on the Internet web system) [22], which provides hourly, daily, and annual data on near-Earth solar wind magnetic field, plasma parameters, energetic particles, and geomagnetic activity indices.

Research Methodology

The duration of solar flares was studied for solar cycles 23 and 24 as follows:

1) Calculating the total monthly duration time of solar flares (TMDSF) and the monthly average for each of Kp and F10.7 for a period from 1996 to 2019 as shown in Figure 1.

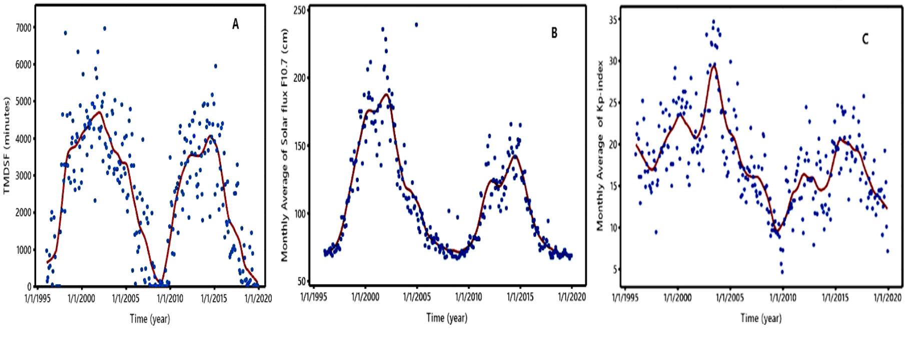

FIGURE 1. *The monthly average of the data: (a) of the total monthly duration time of solar flares; (b) of the solar flux F10.7; (c) of the Kp-index.*

2) Ordering the duration time of solar flares into five groups (<30, 30-60, 60-90, 90-120, >120) of minutes and calculating the total annual durations time of solar flares of the group (TADSFG), as shown in Figure 2.

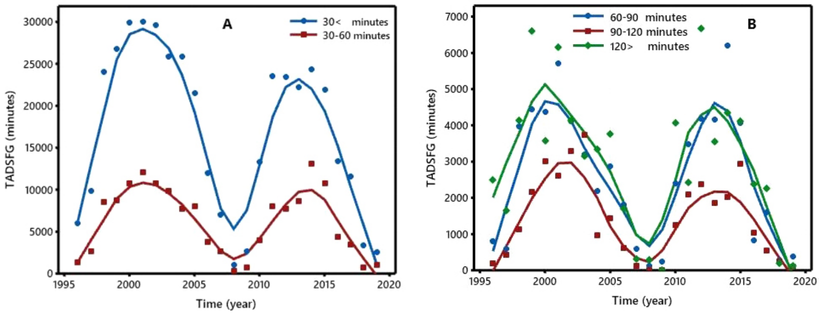

FIGURE 2. *Total annual duration time of solar flares of the groups: (a) for groups (<30 and 30–60 minutes); (b) for groups (60–90, 90–120 and >120 minutes.*

3) Calculating the total annual duration time for each solar flare classification class (TADSFC) (B, C, M, X), as shown in Figure 3. The rising duration time, ranging from the onset of the solar flare to the peak, where the total annual duration time of rising (TDR) of each solar flare type is calculated, as well as the decay duration time, ranging from the peak to the end of the solar flare, and the total duration time of decay (TDD).

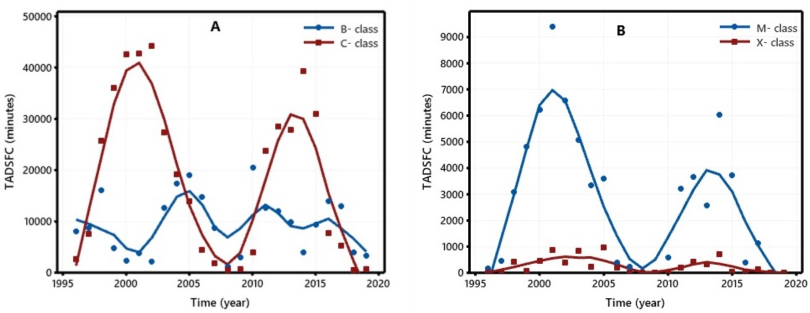

FIGURE 3. *Total monthly duration time of solar flares: (a) for B-class and C-class; (b) for M-class and X-class.*

4) Conducting a statistical analysis to find the relationship between the solar flare duration time (monthly and annual) and each of the Kp and F10.7 indices for the 23 and 24 solar cycles, using the Minitab 19.0 program, which is considered one of the most accurate programs. Finding the linear regression between the statistically calculated variables and the linear correlation relationship (Pearson's coefficient) also between them [23].

Results and discussion

Analysis of the duration time of solar flares

From Figure 4 of the Histogram chart, we noticed the distribution of the DSFs for the four classes (B, C, M, X) and the two solar cycles 23 and 24, where the largest number of solar flares for class B23 and B24 are between the time durations (6-8 minutes), representing 21.5 % and 19.9 % respectively, of the total number of class B solar flares for each solar cycle. While the overall average for class B duration time is 14.5 and 16.4 minutes respectively.

The duration time for classes C23 and C24 is between 8-10 minutes, representing 13.5 % and 12.3 % of the total time respectively. The overall average duration time for class C23 is 20.5 minutes and for class C24 is 21.5 minutes.

The duration time for classes M23 and M24 is between 10 12 minutes, representing 8.4 % and 10 % respectively. The overall average for the duration time class M is (30.4 and 28.4 minutes) respectively. While the X-class has two different peaks, solar cycle 23 has a time duration between 8-10 and 20-22 minutes, representing 13 %, and cycle 24 has a time duration between 20-22 minutes, representing 10.2 % of the total number of X24. The overall average for the time duration of X-class is 35.0-36.6 minutes respectively.

We conclude that approximately 41 % of solar flares occur between 6 and 12 minutes for solar cycles 23 and 24. The total average of their time duration is 19.1 and 19.6 minutes respectively.

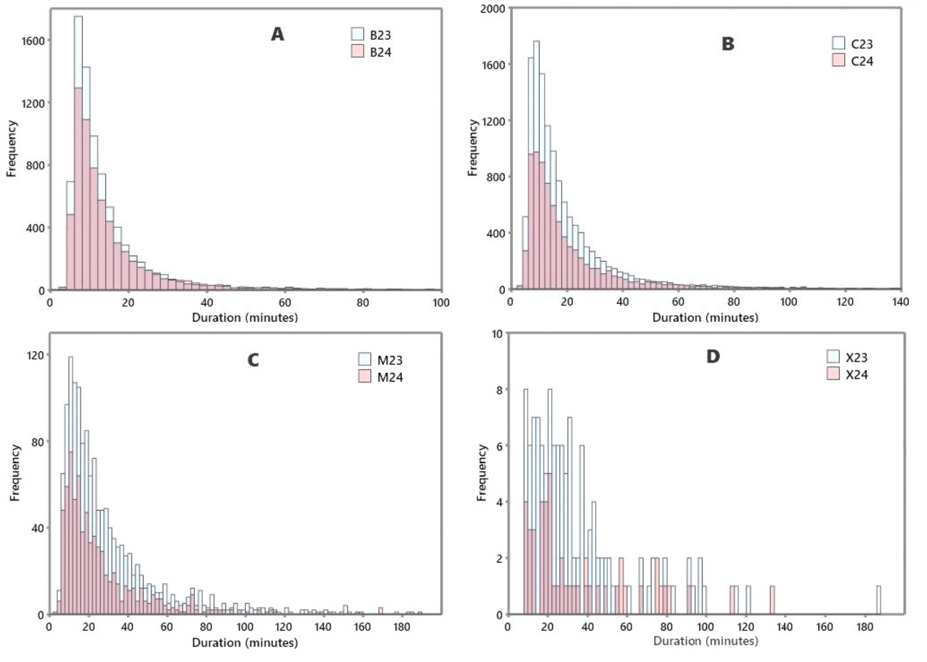

FIGURE 4. *Histograms of solar flare duration time according to solar flare classification: (a) for B23, B24-class; (b) for C23, C24-class; (c) for M23, M24-class; (d) for X23, X24-class.*

From Figure 5 of the Histogram chart, we notice that the major number of solar flares have duration time rises for classes B23, B24, C23, C24 between 4-6 minutes, which represent 40.5 %, 38.75 %, 29.9 %, 27.36 % of the total number for each of them respectively. The duration time decays of the classes C23, C24, M23, M24 between 22.47 %, 21.4 %, 16.6 %, 18.6 % respectively of the total number for each of them.

The major number of solar flares of B23, B24-classes have a duration time decay between 2-4 minutes and represent 38.7 % and 32.6 % respectively. The duration time rises of classes M23 and M24 and the duration time decays of class X23 are between 6-8 minutes, accounting for 15.6 %, 18.8 % and 14.3 % respectively. Class X23 had the highest number of solar flares for duration time rises (between 10-12 minutes), which accounted for 12.7 %,

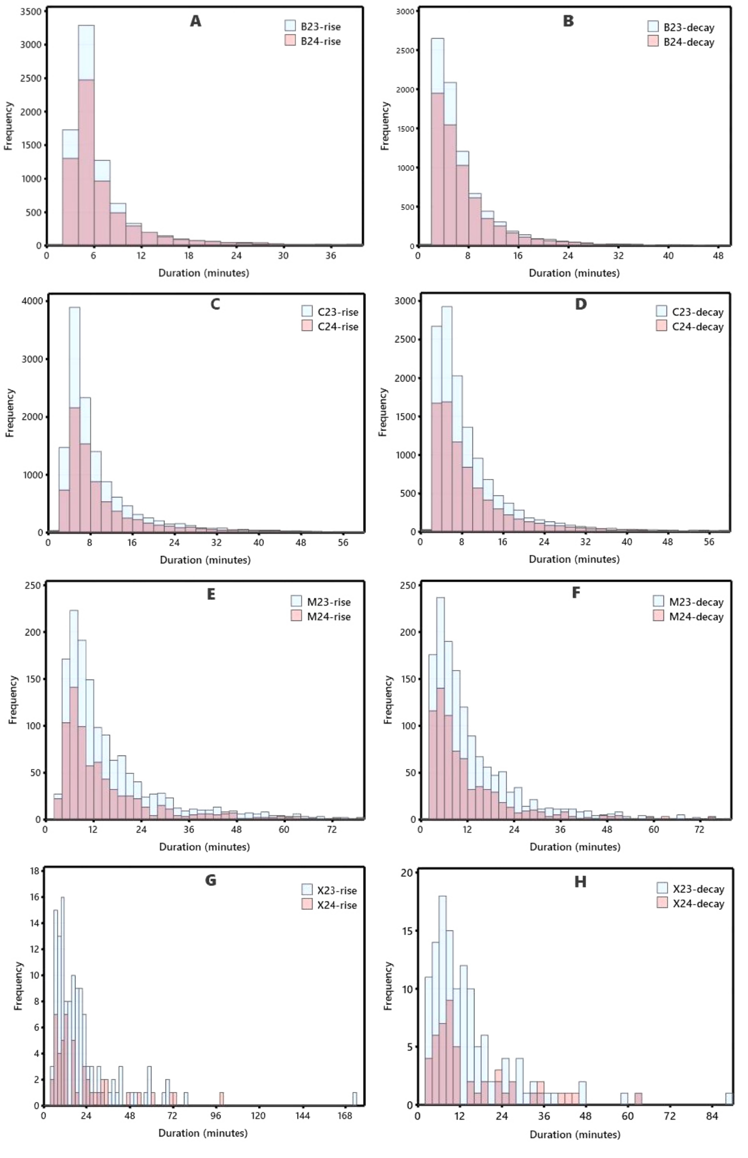

FIGURE 5. *Duration time of solar flares (rises and decays) according to solar flares classification: (a) for B23, B24-class-rise; (b) for B23, B24-class-decay; (c) for C23, C24-class-rise; (d) for C23, C24-class-decay; (e) for M23, M24-class-rise; (f) for M23, M24-class-decay; (g) for X23, X24-class-rise; (h) for X23, X24-class-decay.*

while class X24 had two groups of duration time rises between 6-8 and 12-14 minutes, which accounted for 14.3 %. Regarding class X24, the duration time decays were between 8-10 minutes, which accounted for 18.4 %. We conclude that approximately 62-63 % of solar flares have duration rises and decays between 2-8 minutes for solar cycles 23 and 24.

Table 1 presents the averages of the duration time of all classes of solar flares (the total duration time, the rising duration time, the falling duration time) and solar cycles 23 and 24 for the ascending and descending phases. It is observed that the lowest mean duration time of a solar flare corresponds to class B, especially in the descending phase of solar cycle 23 of the decay stage, whose average duration time is 6.91 minutes. In contrast, the mean solar flare duration time increases as one moves to class X, and the highest average value is for the total duration time of the descending phase of solar cycle 24 for class X (39.82 minutes).

Solar cycle	B-class (minutes)			C-class (minutes)			M-class (minutes)			X-class (minutes)		
	Total	Rise	Decay	Total	Rise	Decay	Total	Rise	Decay	Total	Rise	Decay
As. Sc23	15.42	7.31	8.12	20.34	10.16	10.18	29.94	16.13	13.81	31.02	17.82	13.20
De. Sc23	14.04	7.12	6.91	20.89	11.02	9.87	30.99	16.93	14.06	38.71	23.56	15.15
Sc23	14.52	7.19	7.33	20.57	10.51	10.06	30.40	16.48	13.92	35.05	20.83	14.22
As. Sc24	16.78	8.84	7.94	20.70	11.04	9.66	27.61	15.60	12.01	33.93	22.44	11.48
De. Sc24	15.92	8.15	7.77	22.26	11.99	10.28	29.17	16.31	12.86	39.82	20.73	19.09
Sc24	16.39	8.52	7.86	21.45	11.49	9.96	28.41	15.97	12.45	36.57	21.67	14.90

TABLE 1. *Average time of duration for all classes of solar flares (total, rise, decay) and for solar cycles 23 and 24 (ascending and descending phase).*

Table 2 represents the duration time averages for all groups for solar flares (<30, 30-60, 60-90, 90-120, >120) and the solar cycles 23 and 24 for the ascending and descending phases. It is noted that all groups are at very close averages, except for the group >120, whose averages vary with the phases of the two cycles.

We also note in Tables 1-3, and in Figure 5 that solar cycle 23 is more active than solar cycle 24, and that cycle 23 is more coordinated since the large time durations are almost equally distributed between the ascending and descending phases. As for cycle 24, most of the maximum durations occur in the ascending

Solar cycle	<30 (minutes)	30-60 (minutes)	60-90 (minutes)	90-120 (minutes)	>120 (minutes)
As. Sc23	12.84	41.12	73.76	103.26	234.29
De. Sc23	12.35	40.72	72.66	103.54	179.80
Sc23	12.60	40.92	73.28	103.41	208.99
As. Sc24	12.43	41.27	73.52	103.67	202.07
De. Sc24	12.64	41.84	72.87	103.79	175.83
Sc24	12.53	41.57	73.21	103.73	189.61

TABLE 2. *Averages durations time for all groups of solar flares (<30, 30-60, 60-90, 90-120, >120) and for the solar cycles 23&24 (Ascending phase and Descending phase).*

phase. Moreover, the mean time duration of the ascending phase is shorter than that of the descending phase of solar cycles 23 and 24 for all classes of solar flares, except for class B, which is vice versa.

The duration-time relationship of solar flares with F10.7 and Kp indices

A. Correlation of the TMDSF with the monthly average for each of the F10.7 and Kp-indices

Figure 6 shows the statistical relationship between the monthly average of each of the F10.7 and Kp-indices with the Total Monthly Durations Time of Solar Flares (TMDSF) for the solar cycles 23 (1996-2007) and 24 (2008-2019). The relationship is a strong direct relation to the F10.7, where Pearson's coefficient reached (R=79.6 %), and Kp-index is a medium relationship, where Pearson's coefficient reached them (R=48.7 %), and with statistical significance its value (Sig=0.0) for all. Thus, the solar flux F10.7 is affected by the duration time of the solar flare.

B. The correlation of the total annual durations time of solar flares of the group (TADSFG) (<30, 30-60, 60-90, 90-120, >120) with the annual mean for each of F10.7 and Kp- indices

From (Figure 7) and Table 4, observe that the relationship between the annual mean F10.7 and the five TADSFG groups is a strong

C	X	Date	Duration (minutes)	Fmax*	F10.7 (sfu)	Kp-index
B	Max duration in Sc23	4/3/1998	1497	8.3E-4	95.1	27
	Max duration in Sc24	25/2/2013	625	8.9E-4	93.5	7
	Max duration rises in Sc23	4/3/1998	781	8.3E-4	100.0	27
	Max duration rises in Sc24	25/2/2013	396	8.9E-4	93.5	10
	Max duration decay in Sc23	16/9/1998	855	6.8E-4	119.25	17
	Max duration decay in Sc24	31/3/2015	271	7.5E-4	127.8	23
C	Max duration in Sc23	19/12/1997	1673	1.1E-3	86.8	3
	Max duration in Sc24	10/4/2016	435	1.5E-3	111.1	17
	Max duration rises in Sc23	23/2/2001	1385	2.2E-3	142.2	23
	Max duration rises in Sc24	4/8/2012	236	3.5E-3	142.7	13
	Max duration decay in Sc23	20/10/2003	1375	6.2E-3	150.2	43
	Max duration decay in Sc24	1/5/2013	321	2.5E-3	161.7	47
M	Max duration in Sc23	21/10/2003	463	2.4E-2	150.2	60
	Max duration in Sc24	17/7/2012	421	1.7E-2	131.7	27
	Max duration rises in Sc23	21/10/2003	248	2.4E-2	152.0	47
	Max duration rises in Sc24	17/7/2012	312	1.7E-2	131.7	23
	Max duration decay in Sc23	21/10/2003	215	2.4E-2	150.2	57
	Max duration decay in Sc24	14/10/2014	178	1.0E-2	131.9	50
X	Max duration in Sc23	17/1/2005	188	3.8E-1	133.1	60
	Max duration in Sc24	5/3/2012	133	1.1E-1	129.5	20
	Max duration rises in Sc23	17/1/2005	173	3.8E-1	133.1	50
	Max duration rises in Sc24	5/3/2012	99	1.1E-1	129.5	23
	Max duration decay in Sc23	13/9/2005	90	1.5E-1	115.0	47
	Max duration decay in Sc24	25/10/2014	63	1.0E-1	216.8	30

*(erg cm-2 s-1 = 10-3 W m-2).

TABLE 3. *Information about the different Maximum DSFs, with Kp and F10.7 indices for the two solar cycles 23 & 24.*

linear relationship and statistically significant. As for the annual average for Kp-index, it is found to be between a strong middling (with groups (<30, 30- 60, 90-120) minutes) and a weak middling (with groups (60-90,>120) minutes) and are statistically significant. With the exception of the group (60-90 minutes) the value of (sig = 0.063), which is greater than (0.05), has not any statistical significance.

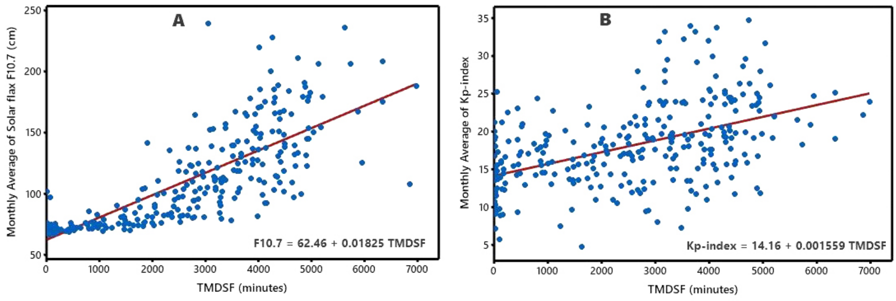

FIGURE 6. *The correlation of the total monthly duration time of solar flares with: (a) F10.7; (b) Kp- index.*

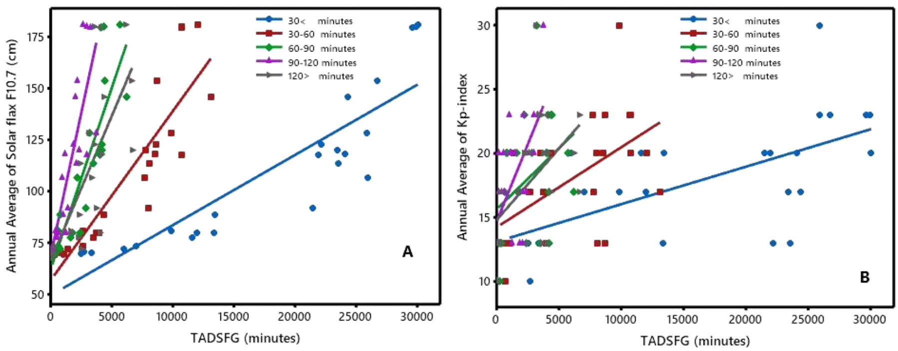

FIGURE 7. *The correlation of the total annual duration time of solar flares of the groups with: (a) F10.7; (b) Kp- index.*

C. The correlation of the total annual duration time for each class of solar flare classification (TADSFC) (B, C, M, X) with the annual average for each Kp and F10.7-indices

Figure 8 and Table 5 show the correlation of the TADSFC (B, C, M, X) with the Annual Average for Each Kp-Index and F10.7. Note that B-class solar flare during the period 1996-2019 does not form a relationship with F10.7 and Kp-index, because the values of Pearson's coefficient are few and the values of Sig are greater than 0.05 and indicate that they have no statistical significance.

The solar flux (F10.7) had a very strong linear relationship with the two C, M-classes of the solar flare and during the solar cycles

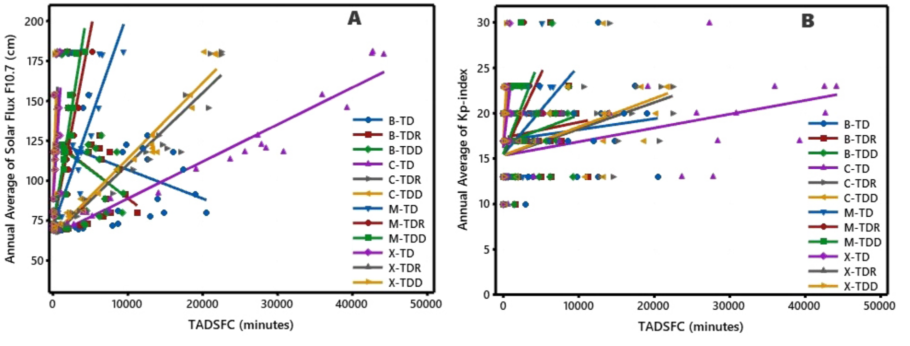

FIGURE 8. *Correlation of the total annual duration time for each class of solar flare classification with: (a) F10.7; (b) Kp- index.*

23 and 24, especially with a total duration time of decay for C-class (C-TDD). The value of Pearson's coefficient (R=98 %) is because the longest duration time of the solar flare is at C-class. Its relationship with the X-class is medium because it has a short duration time. As for the Kp-index, their relationship is linear, and medium, with each of the classes (C and M) of the solar flare, and it is moderately weak with the X-class.

Y	X	Regression eq.	R	Sig
F10.7	30<	49.38 + 0.00341X	0.89	0.000
Kp-index	30<	13.10 + 0.000293X	0.62	0.001
F10.7	30-60	56.69 + 0.008219X	0.89	0.000
Kp-index	30-60	14.23 + 0.000624X	0.55	0.005
F10.7	60-90	62.05 + 0.01762X	0.87	0.000
Kp-index	60-90	15.64 + 0.000956X	0.39	0.063
F10.7	90-120	68.52 + 0.02776X	0.86	0.000
Kp-index	90-120	14.71 + 0.002408X	0.60	0.002
F10.7	120>	66.10 + 0.01408X	0.74	0.000
Kp-index	120>	14.81 + 0.001117X	0.48	0.019

TABLA 4. *Regression equations and Pearson's coefficient for TADSFG with each of F10.7 and Kp- index.*

Y	X	Regression eq.	R	Sig
F10.7	B-TD	124.8 - 0.001805X	-0.280	0.186
Kp-index	B-TD	17.00 + 0.000121X	0.152	0.479
F10.7	B-TDR	125.1 - 0.003634X	-0.292	0.167
Kp-index	B-TDR	17.31 + 0.000171X	0.112	0.603
F10.7	B-TDD	124.1 - 0.003517X	-0.265	0.211
Kp-index	B-TDD	16.67 + 0.000316X	0.193	0.365
F10.7	C-TD	65.68 + 0.002319X	0.975	0.000
Kp-index	C-TD	15.36 + 0.000152X	0.519	0.009
F10.7	C-TDR	65.31 + 0.004494X	0.965	0.000
Kp-index	C-TDR	15.35 + 0.000293X	0.511	0.011
F10.7	C-TDD	66.46 + 0.004749X	0.980	0.000
Kp-index	C-TDD	15.39 + 0.000313X	0.525	0.008
F10.7	M-TD	71.75 + 0.01343X	0.949	0.000
Kp-index	M-TD	15.49 + 0.000977X	0.561	0.004
F10.7	M-TDR	71.65 + 0.02454X	0.939	0.000
Kp-index	M-TDR	15.50 + 0.001778X	0.553	0.005
F10.7	M-TDD	72.10 + 0.02946X	0.957	0.000
Kp-index	M-TDD	15.50 + 0.002155X	0.569	0.004
F10.7	X-TD	89.27 + 0.07210X	0.594	0.002
Kp-index	X-TD	16.29 + 0.007112X	0.476	0.019
F10.7	X-TDR	88.52 + 0.1263X	0.598	0.002
Kp-index	X-TDR	16.18 + 0.01267X	0.487	0.016
F10.7	X-TDD	90.83 + 0.1627X	0.579	0.003
Kp-index	X-TDD	16.48 + 0.01568X	0.453	0.026

TABLA 5. *Regression equations and Pearson's coefficient for TADSFC with each of F10.7 and Kp- index.*

Conclusions

The duration time of the solar flare has been studied for solar cycles 23 and 24, which is one of its parameters, as well as the relationship of the duration of the flare with each of the F10.7 and Kp indices, which measures the effects produced in the Earth's atmosphere.

The distribution of DSFs was studied for the four classes (B, C, M, X) and for the two solar cycles 23 and 24. The highest number of solar flares for all classes of solar cycles 23 and 24 are between the duration times (6-8, 8-10, 10-12, [8-10, 20-22]) respectively, of the total number of solar flares for each class for each solar cycle. The overall averages of the duration time for each class of solar cycle 23 were determined with values of 14.5, 20.5, 30.4, 35.0 minutes respectively, and solar cycle 24 were 16.4, 21.5, 28.4, 36.6 minutes respectively.

It was also found that about 41 % of solar flares occur within 6-12 minutes for the solar cycles 23 and 24. The total average of their duration time is 19.1, 19.6 minutes respectively. In addition, the average duration time of the ascending phase is less than the descending phase of the solar cycles 23 and 24 for all classes of solar flares, except for B-class, which is vice versa. In addition, all groups for solar flares <30, 30-60, 60-90, 90-120, >120 are at very close averages, except for group >120, whose averages vary within the phases of the two cycles.

In this work, the relationship between TMDSF with the monthly average of each of the F10.7 and Kp-index for solar cycles 23 and 24 showed a strong direct relation to the F10.7. This means that there is an increase in the emission of ultraviolet rays that reach the earth with an increase in the duration time of the flare. In contrast, it was found that the effect of the duration time of solar flares on the Earth's magnetic field is weak.

Acknowledgments

I would like to express my thanks and gratitude to the University of Mosul for its provided services.

References

[1] P. V. Foukal, *The Sun, Our Variable Star. In Solar Astrophysics* (John Wiley & Sons, Ltd, 2004).

[2] P. K. F. Grieder, *Cosmic Rays at Earth* (Elsevier Science, 2001).

[3] M. A. Ramadan and I. A. Hussain, J Sci Malays **41**, 76 (2022).
[4] D. G. Alvarez, Irish Astr J **27**, 117 (2000).
[5] A. O. Acebal, *Extending F10.7's Time Resolution to Capture Solar Flare Phenomena* (Utah State University (doctoral thesis), 2008).
[6] M. J. Aschwanden, *Physics of the Solar Corona. An Introduction with Problems and Solutions* (Praxis Publishing Ltd., 2004).
[7] P. R. Singh, A. K. Saxena, and C. M. Tiwari, J Astrophys Astron **39**, 20 (2018).
[8] A. Veronig and et al., Solar Physics **208**, 297 (2002).
[9] E. A. Bruevich, J Astrophys Astron **41**, 3 (2020).
[10] G. A. Bazilevskaya, Y. I. Logachev, and et al., B Russ Acad Sci Phys **79**, 573 (2015).
[11] E. A. Bruevich and G. V. Yakunina, Astrophysics **60**, 387 (2017).
[12] E. A. Bruevich and V. V. Bruevich, Astrophysics **61**, 241 (2018).
[13] X. L. Yan, L. H. Deng, and et al., J Astrophys Astron **33**, 387 (2012).
[14] W. M. A. W. Ismail, Z. S. Hamidi, and N. N. M. Shariff, AIP Conf Proc **2368**, 040006 (2021).
[15] E. A. Bruevich, V. V. Bruevich, and G. V. Yakunina, J Astrophys Astron **35**, 1 (2014).
[16] Z. S. Hamidi and et al., ILCPA **38**, 160 (2014).
[17] J. Palacios, A. Guerrero, C. Cid, E. Saiz, and Y. Cerrato, Nat. Hazards Earth Syst. Sci. Discuss. **preprint**, 1 (2018).
[18] T. T. Yamamoto and T. Sakurai, PASJ **61**, 75 (2009).
[19] S. Kołomanski, T. Mrozek, and U. Bak-Steslicka, A&A **531**, A57 (2011).
[20] J. W. Reep and K. J. Knizhnik, The Astrophysical Journal **874**, 157 (2019).
[21] NOAA, The national oceanic and atmospheric administration (2016).

[22] NASA, Omni web plus (consulted in Jul 2022).
[23] G. Currell, *Scientific Data Analysis* (Oxford University Press (UK), 2015).