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Relationship between SSN, F107 and Z component of EMF during the 24th Solar Cycle

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ABSTRACT

The study inquires the statistical relationship between Solar activity indices SSN, $F_{10.7}$ and Earth's Magnetic Field (EMF) Z component which were measured in Iznik Magnetic Observatory, for the 24th Solar Cycle. Pearson, Spearman and Kendall Tau-b correlation analysis were made according to the normality analysis of the values which was determined in accordance with skewness and kurtosis values. The highest correlation coefficients were found between the Earth's magnetic field Z component and the SSN (-13.8%) in the negative direction, and 1/ $F_{10.7}$ (15.1%) in the positive direction according to the Pearson correlation analysis. Low level of correlations with high significance were found between the variables.

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1. INTRODUCTION

The Sun, solar winds, magnetosphere, ionosphere, thermosphere and variations in the Earth's magnetic field interact in an intricate manner. Earth's magnetic field comes from two main sources; internal and external. The internal source is the interaction of the Earth's core with the mantle and the external source is the electrical currents called Field Aligned Current (FAC) that connects the ionosphere and magnetosphere. The FAC occurs by the solar winds connects the currents in these two layers that surround the Earth through the ionosphere. The magnetic field components measured at the Earth's surface are generated by the total field formed by the various magnetic fields in the core, earth, ionosphere, and magnetosphere [1–10].

The solar cycle, known as the variation in sunspots, was discovered in 1843 by Samuel Heinrich Schwabe. The solar cycles have an average duration of 11 years, and the cycle numbering begins at one with the 1755-1766 cycle. The Solar activity index is derived from counting the number of visible sunspots on the Sun surface and called the International Sunspot Number (SSN) [11]. Another index of solar activity is the $F_{10.7}$ value, which indicates the flux value at 10.7 cm wavelength obtained from the solar observation [4, 12–15].

In this study, the relationship between SSN, $F_{10.7}$ and the Z component of the Earth's magnetic field during the 24th solar cycle (years of 2008- 2019) was studied statistically [16, 17].

2. Material and Method

The SSN and $F_{10.7}$ data were taken from the Omni website, a service of NASA, and the Z component data of the Earth's magnetic field was taken from the INTERMAGNET website for the Iznik Magnetic Field Observatory (49.5 N, 29.72E, IZN) [18]. The Z component of the Earth's magnetic field represents the z axis on the Cartesian coordinate system, which points to the center of the Earth according to the measurement location. The daily changes of SSN, $F_{10.7}$ and the Z component of the Earth's magnetic field during 24th the solar cycle are given in Figure 1 and Figure 2, respectively.

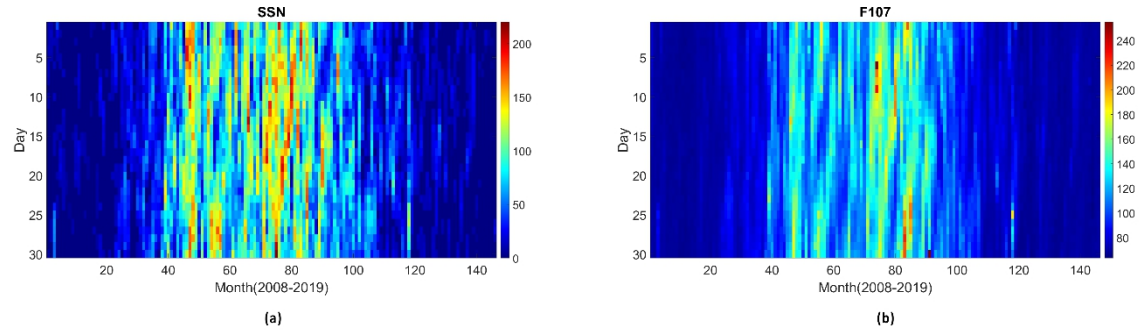

Figure 1. Daily averaged Solar indices during 24th SC. (a) SSN (b) $F_{10.7}$

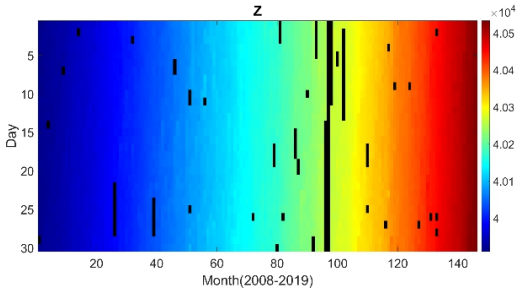

Figure 2. Daily averaged of Z component of EMFC during 24th SC (The black cells are the unmeasured days.).

Table 1. The Skewness values and the classification table of SSN, $F_{10.7}$ and Z

Skewness	SSN	Log (SSN)	$\frac{1}{SSN}$	$\sqrt{SSN}$	F10.7	Log (F10.7)	$\frac{1}{F_{10.7}}$	$\sqrt{F_{10.7}}$	Z	Log (Z)	$\frac{1}{Z}$	$\sqrt{Z}$
Highly Skw. 1<Skw Skw<-1					1.14							
Mod. Skw. 0.5 <Skw <1 -1 <Skw <-0.5	0.94	-0.57	0.99			0.70		0.90				
Fairly symmetrical 0.5<Skw<0.5				0.06			-0.40		0.34	0.33	-0.32	0.33

The relationship between SSN, $F_{10.7}$ and the Z component of the Earth's magnetic field was examined with Bivariate Correlation tests. In order to make the correlation tests, firstly, determined the normality of variables. Each variable and their mathematical transformations were classified according to skewness and kurtosis values according to normality distribution analysis. The SSN index has the value of "0", so that, the SSN+1 value is used in the Log(SSN) and 1/SSN transformations. Skewness classification was made as Fairly symmetrical, moderately skewed and Highly skewed, and Kurtosis as Mesokurtic, Platykurtic and Leptokurtic. [19]. Fairly symmetrical, Medium skewness and Mesokurtic classes were accepted as **Normal** and Pearson Correlation analysis was applied and Spearman and Kendall Tau-b Correlation analyzes were applied to the other groups [20–25].

Table 2. The Kurtosis values and the classification table of SSN, $F_{10.7}$ and Z

Kurtosis	SSN	Log (SSN)	$\frac{1}{SSN}$	$\sqrt{SSN}$	$F_{10.7}$	Log (F10.7)	$\frac{1}{F_{10.7}}$	$\sqrt{F_{10.7}}$	Z	Log (Z)	$\frac{1}{Z}$	$\sqrt{Z}$
Platykurtic Krt <-0.5		-1.24	-0.99	-1.21	0.78		-1.26		-1.05	-1.05	-1.05	-1.02
Leptokurtic Krt> 0.5						-0.68						
Mesokurtic -0.5 <Krt < 0.5	-0.09							-0.13				

3. Results and Discussion

The Z component of the Earth's magnetic field during the 24th solar cycle was not measured for 131 days.

Z component was measured minutely and converted to daily averaged. Skewness Standard Error = 0.038, Kurtosis Standard Error = 0.075 for the rest 4252 days of the analysis.

The Skewness and Kurtosis values obtained by the normality analysis for SSN, $F_{10.7}$ and the Z component of the Earth's magnetic field and their mathematical transformations are given and classified in Table 1 and Table 2, respectively.

According to the skewness table, except $F_{10.7}$, all the variables are in the Fairly symmetrical and Moderately skewed classes, which are accepted Normal. In the Kurtosis table, the Z component of the Earth's magnetic field and any of its mathematical transformations could not be found in the Mesokurtic class, so all of the variables were accepted as **Non-Normal**. The Pearson correlation table for SSN, $F_{10.7}$, Z and their mathematical transformations that are accepted **Normal** according to skewness are given in Table 3, and the Spearman and Kendall Tau-b correlation table for those that are accepted **Non-Normal** are given in Table 4. The " ** " sign next to the values in these tables means that the significance level of the correlation value is less than 1%, so the significance is very high.

Table 3. The Pearson correlation table for SSN, F10.7, Z and their mathematical transformations accepted **Normal** according to skewness

Pearson Skw.	SSN	Log (SSN)	$\frac{1}{SSN}$	$\sqrt{SSN}$	Log ($F_{10.7}$)	$\frac{1}{F_{10.7}}$	$\sqrt{F_{10.7}}$
Z	-,138**	-,126**	,094**	-,138**	-,143**	,151**	-,137**
Sig.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Log (Z)	-,137**	-,124**	,093**	-,137**	-,141**	,150**	-,135**
Sig.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$1/Z$	,135**	,123**	-,091**	,135**	,140**	-,148**	,134**
Sig.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\sqrt{Z}$	-,137**	-,125**	,093**	-,138**	-,142**	,150**	-,136**
Sig.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4. The Spearman and Kendall Tau-b correlation table for $F_{10.7}$, Z and it's mathematical transformations which are accepted **Non-Normal** according to skewness

Spearman Skw.	$F_{10.7}$	Kendall Tau-b Skw.	$F_{10.7}$
Z	-,047**	Z	-,029**
Sig.	0.0021	Sig.	0.0046
Log (Z)	-,047**	Log (Z)	-,029**
Sig.	0.0021	Sig.	0.0046
$1/Z$	,047**	$1/Z$	,029**
Sig.	0.0021	Sig.	0.0046
$\sqrt{Z}$	-,047**	$\sqrt{Z}$	-,029**
Sig.	0.0021	Sig.	0.0046

Table 5. The Spearman correlation table for SSN, F10.7, Z and their mathematical transformations which are accepted **Normal** according to kurtosis

Spearman Krt.	SSN	Log(SSN)	$\frac{1}{SSN}$	$\sqrt{SSN}$	$F_{10.7}$	Log ($F_{10.7}$)	$\frac{1}{F_{10.7}}$	$\sqrt{F_{10.7}}$
Z	-,042**	-,042**	,042**	-,042**	-,047**	-,047**	,047**	-,047**
Sig.	0.006	0.006	0.006	0.006	0.002	0.002	0.002	0.002
Log (Z)	-,042**	-,042**	,042**	-,042**	-,047**	-,047**	,047**	-,047**
Sig.	0.006	0.006	0.006	0.006	0.002	0.002	0.002	0.002
$1/Z$	,042**	,042**	-,042**	,042**	,047**	,047**	-,047**	,047**
Sig.	0.006	0.006	0.006	0.006	0.002	0.002	0.002	0.002
$\sqrt{Z}$	-,042**	-,042**	,042**	-,042**	-,047**	-,047**	,047**	-,047**
Sig.	0.006	0.006	0.006	0.006	0.002	0.002	0.002	0.002

Table 6. The Kendall Tau-b correlation table for SSN, F10.7, Z and their mathematical transformations which are accepted **Non-Normal** according to kurtosis

Kendall Tau-b Krt.	SSN	Log (SSN)	$\frac{1}{SSN}$	$\sqrt{SSN}$	$F_{10.7}$	Log ($F_{10.7}$)	$\frac{1}{F_{10.7}}$	$\sqrt{F_{10.7}}$
Z	-,039**	-,039**	,039**	-,039**	-,029**	-,029**	,029**	-,029**
Sig.	0.0002	0.0002	0.0002	0.0002	0.0046	0.0046	0.0046	0.0046
Log (Z)	-,039**	-,039**	,039**	-,039**	-,029**	-,029**	,029**	-,029**
Sig.	0.0002	0.0002	0.0002	0.0002	0.0046	0.0046	0.0046	0.0046
$1/Z$	,039**	,039**	-,039**	,039**	,029**	,029**	-,029**	,029**
Sig.	0.0002	0.0002	0.0002	0.0002	0.0046	0.0046	0.0046	0.0046
$\sqrt{Z}$	-,039**	-,039**	,039**	-,039**	-,029**	-,029**	,029**	-,029**
Sig.	0.0002	0.0002	0.0002	0.0002	0.0046	0.0046	0.0046	0.0046

Spearman and Kendall Tau-b correlation tables for SSN, $F_{10.7}$, Z and their mathematical transformations, which are accepted **Non-Normal** according to kurtosis, are given in Table 5 and Table 6, respectively.

4. Conclusion

In this study, the correlation relationship between the Solar indices SSN and $F_{10.7}$ and the Z component of the Earth's magnetic field during the 24th solar cycle was investigated. In the Pearson, Spearman and Kendall Tau-b correlation analysis, the significance levels were found to be less than 1%. According to the Pearson correlation analysis, the highest correlation coefficient between the Earth's magnetic field Z component and the SSN was found to be -13.8% in the negative direction, and 1/ $F_{10.7}$ was 15.1% in the positive direction. According to Spearman and Kendall Tau-b correlation analysis, it was found to be -4.2% between Z and SSN and -4.7% with $F_{10.7}$.

As a result, statistically significant but weak correlations were found between the Solar activity indices and the Earth's magnetic field Z component. These statistical analyzes show that there is a low level of interaction between the activity changes in the Sun during the 24th solar cycle and the Earth's magnetic field Z component measured at the Earth's surface.

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