Comparison of FI and the MCMESI for the Last Two Solar Cycles

Kilcik A. [1], *Ozguc A.* [2], *Yesilyaprak H.* [2], *Pektas R.* [2]

[1] Akdeniz University Faculty of Science, Department of Space Science and Technologies, 07058, Antalya, Turkey
[2] Kandilli Observatory and Earthquake Research Institute, Bogazici University, 34684 Istanbul, Turkey
E-mail: alikilcik@akdeniz.edu.tr

Abstract.

Here, we used Hα flare index (FI) data taken from Bogazici University Kandilli Observatory for the time period of January 1996– March 2018 (total 8127 days), which covers Cycle 23 completely and almost whole cycle 24 (2009-2018). This data set compared with the maximum CME speed index (MCMESI) data during the studied time period. Then temporal and periodic variations of hemispheric and whole data were analyzed by using the cross-correlation analysis method, Morlet wavelet, MTM period analysis methods and wavelet coherence analysis. It is found that; i) the temporal variation of northern and southern hemisphere FI data sets show remarkable differences, ii) both northern and southern hemisphere FI data show the same level of correlation (r = 0.48) which is lower than the total FI data (r = 0.58), with the MCMESI, iii) these hemispheric FI data sets also show some cyclic differences in periodicity analysis.

Introduction

Solar flares are very strong explosions observed on the solar atmosphere. They generally are observed as intense variation in brightness and are observed around the sunspot groups and are classified in two different ways; 1) X-ray solar flares are classified in 5 classes (A, B, C, M, and X) according to their X-ray peak fluxes in the 1 to 8 Å wavelength band. Each of these classes is also subdivided into 10 subclasses, while the X-class is open-ended. 2) Solar flares are also classified in Hydrogen alpha (Hα, 6563 Å) according to their brightness and the size of brightening area in 15 different classes such as Sn, 4b, 2f etc. According to flaring area brightness there are three main groups as faint (f), normal (n), and bright (b). And for the size of the flaring area there are also five groups as S, 1, 2, 3, and 4.

To describe the solar activity Kleczek J, (1952) introduced a daily flare index (FI) parameter after the regular Hα observations beginning as follows

$$FI = i \times t$$

where i is the flare importance which is a function of a combination of flaring area brightness and size, and t is the duration of flare in minutes. Also the number of observed flares in both X-Ray and Hα classifications can be used as a solar activity indicator.

Coronal Mass Ejections (CMEs) are also another intensive solar events observed in the solar corona. Huge amount of plasma and accompanying magnetic field releases from the solar corona during a CME. Some of them are related to solar flares and prominence eruption. Both solar flare and CME frequencies also follow the solar activity cycle and they have strong geoeffectiveness (Dumbovic M, et al., 2015).

Kilcik A, et al., (2011) introduced a new solar and geomagnetic activity index called the Maximum CME Speed Index (MCMESI) which is a measure of the linear speed of the fastest CME observed in a day.

In this study we investigate the temporal and periodic relationship between the MCMESI and hemispheric and full disc FI data sets.

Data and Methods

Hα flare index (FI) data are taken from Bogazici University Kandilli Observatory as daily values. The CME data are taken from SOHO/LASCO CME catalog (Gopalswamy, et al. 2009) and the maximum CME speed index are calculated as daily values (Kilcik A, et al., 2011). Then monthly values are produced. Hα flare index (FI) data are used for the time period of January 1996–March 2018 (total 8127 days), which covers Cycle 23 completely and almost whole cycle 24 (2009-2018). The temporal variations of hemispheric and full disc FI data sets are compared with the MCMESI data. Cross correlation analyses were applied to hemispheric and full disc FI and the MCMESI data sets. Periodic variations of hemispheric and full disc data were obtained by using the Morlet wavelet (Torrence C and Compo G P, 1998) and MTM (Ghil M et al., 2002) period analysis methods. Coherencies of periodicities are obtained by applying the wavelet coherence analysis method.

Results

We presented the temporal variations (left panel) and cross-correlation analysis results (right panel) in Figure 1. As shown in the left panel of this figure the temporal variation of hemispheric FI data sets show remarkable differences that the northern hemisphere flare index data access to its maximum around the year 2000, while the southern hemisphere FI data access to its maximum around the year 2002 during solar cycle 23. Full disc FI data generally follows the northern hemisphere temporal behavior during the same solar cycle (cycle 23). This result shows that the northern hemisphere was dominant during this cycle. Contrary, the MCMESI data reach to its maximum around 2002 as similar to southern hemisphere FI data. During solar cycle 24 the situation is completely opposite; the MCMESI slightly higher during the first peak of FI at 2012, the southern hemisphere FI is dominant and the hemispheric asymmetry also exists. Again the full disc FI data behave as a combination of hemispheric FI data. When we look at the correlation between FI and the MCMESI data sets we found that both northern and southern hemisphere FI show the same level of correlation (r=0.48) without any time delay, while full disc FI data show higher correlation (r=0.58) with the MCMESI compared to hemispheric FI data.

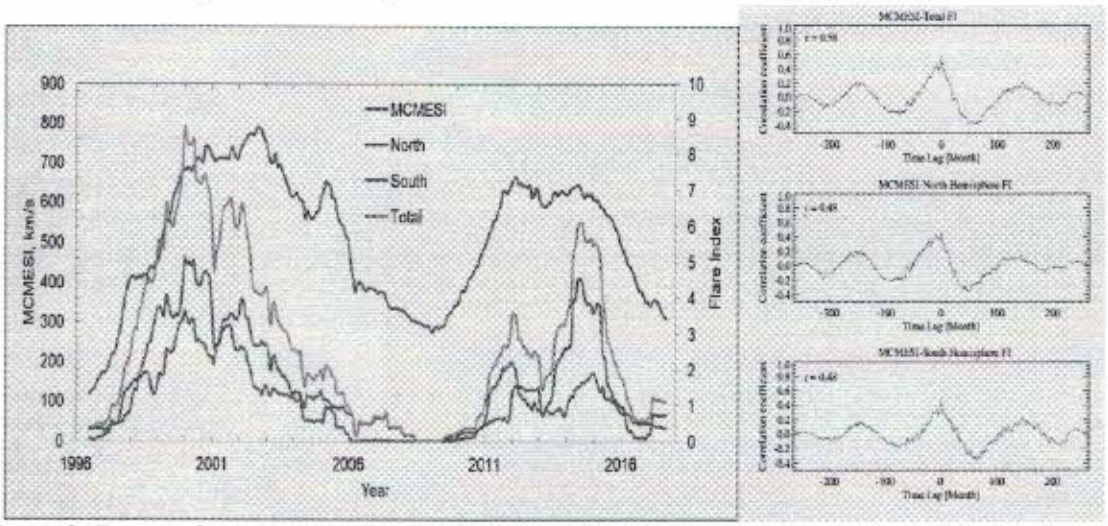


Figure 1. Temporal variations of the hemispheric and total flare index and the MCMESI (left panel) and the cross correlation analysis results for the hemispheric and full disc FI data sets (right panel).

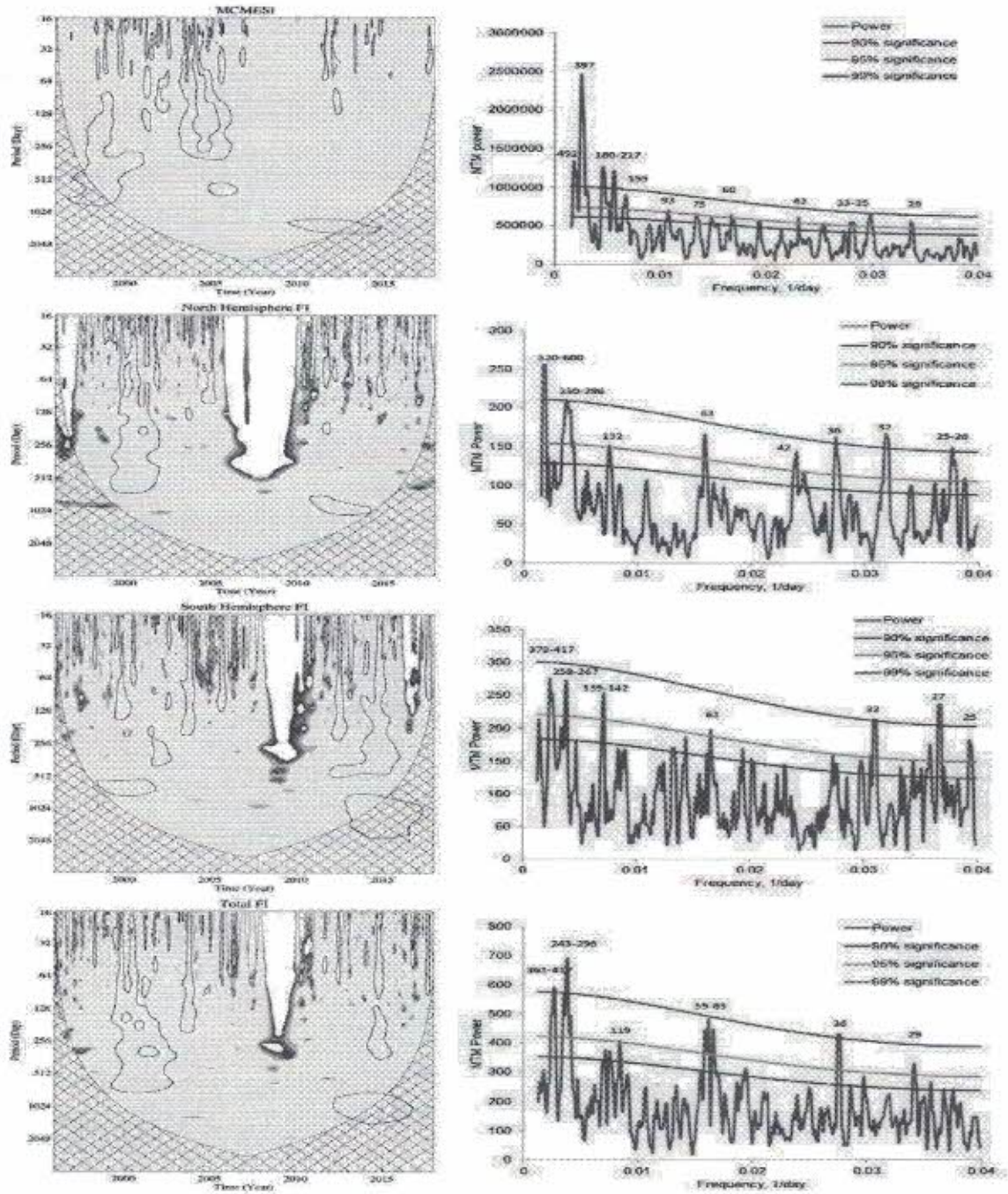


Figure 2. Wavelet (left panel) and MTM (right panel) period analysis results for the MCMESI and FI data sets during the investigated time period (1996-2018).

Figure 2 left panels / right panels show wavelet scalograms / MTM spectra for all data sets used in this study for the investigated time period. From the wavelet power spectrums there are some interesting results i) all periods appear generally during the maximum phases of solar cycles, ii) the MCMESI and the northern hemisphere FI data show similar behavior, while southern hemisphere FI data behave quite differently; during solar cycle 23 the northern hemisphere was dominate, but during solar cycle 24 the situation was opposite, iii) Full disc solar FI data show the combination of northern and southern hemispheres FI data periodic behavior.

In the right panels we presented MTM analysis results that it gives exact periodicities and their significance levels according to the red noise approximation. It is interesting to note that solar rotation periodicity is detected in all cases without any exception. But northern and southern hemispheres solar FI data show some small differences. Note that the periodic behavior of the MCMESI show serious differences from all FI data sets.

As shown in Figure 3 about 11 years periodicity (Schwabe cycle) are in phase in all chases. But the other short term periodicities show some phase differences and these differences also clearly seen in the hemispheric data sets.

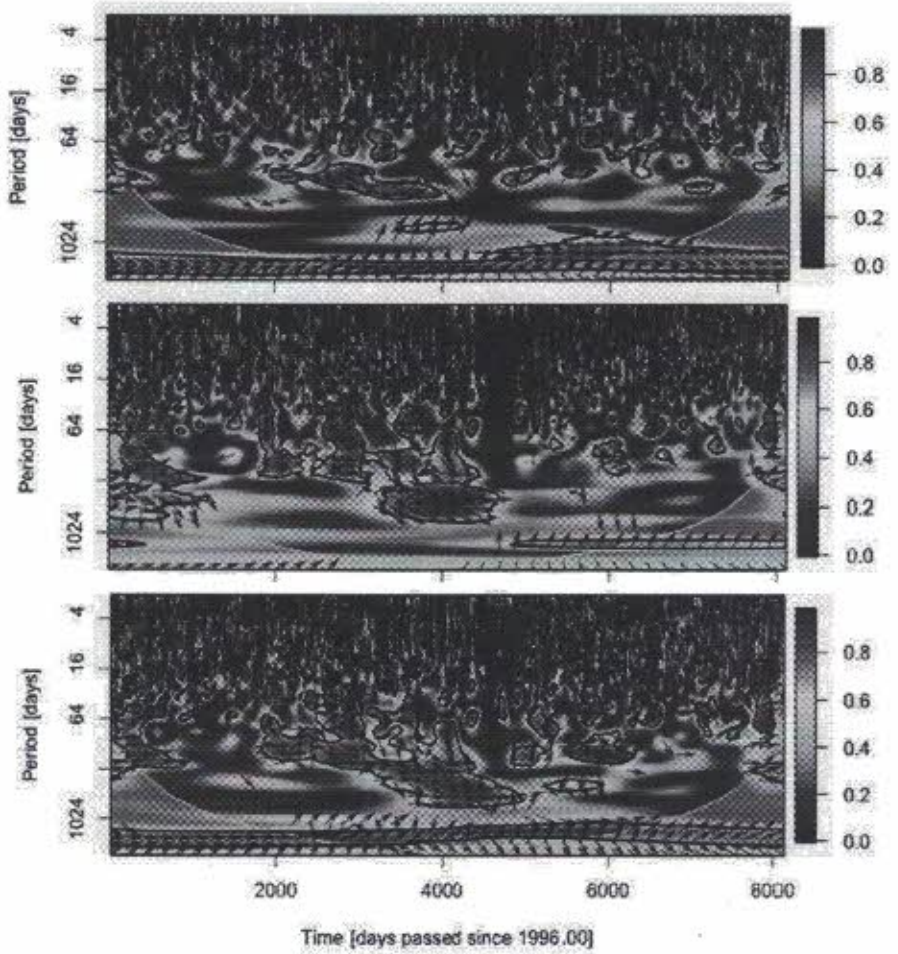


Figure 3. Wavelet coherence of North hemisphere (upper panel), South hemisphere (middle panel) and full disc (lower panel) Hα FI versus the MCMESI during the investigated time period (1996-2018).

Conclusions

Here we compared hemispheric and full disc Hα solar flare index data with the MCMESI for the last two solar cycles and found the followings;

1. The temporal behavior of northern and southern hemispheres FI data show different variations during the investigated time period.
2. Both northern and southern hemispheres FI data show the same level of correlation ($r = 0.48$) which is lower than the total FI data ($r = 0.58$) with the MCMESI.
3. Hemispheric FI data sets also show some cyclic differences in both wavelet and MTM periodicity analysis.
4. The wavelet coherence analysis also reveals some differences between hemispheric data sets

Acknowledgment

Solar FI data are taken from Bogazici University Kandilli Observatory and the CME data are taken from SOHO/LASCO CME catalog. This study was supported by the Scientific and Technical Council of Turkey by the Project of 115F031.

References

Dumbovic, M., Devos, A., Vrsnak, B., Sudar, D., Rodriguez, L., Ruzdjak, D., Leer, K., Vennerstrøm, S., and Veronig, A., 2015, Solar Phys. 290, 579.

Ghil, M., Allen, M.R., Dettinger, M.D., Ide, K., Kondrashov, D., Mann, M.E., Robertson, A.W., Saunders, A., Tian, Y., Varadi, F., Yiou, P.: 2002, Rev. Geophys. 40, 3.1.

Gopalswamy, N., Yashiro, S., Michalek, G., Stenborg, G., Vourlidas, A., Freeland, S., & Howard, R. 2009, Earth Moon Planets, 104, 295.

Kilcik, A., Yurchyshyn, V.B., Abramenko, V., Goode, P.R., Gopalswamy, N., Ozguc, A., Rozelot, J.P.: 2011, Astrophys. J. 727, 44.

Kleczek J., 1952, Publ. Cent. Inst. Astron, No. 22, Prague

Torrence, C., Compo, G.P.: 1998, Bull. Am. Meteorol. Soc. 79, 61.