Long-Term Datasets for the Understanding of Solar and Stellar Magnetic Cycles
Proceedings IAU Symposium No. 340, 2018
D. Banerjee, J. Jiang, K. Kusano & S. Solanki, eds.

doi:10.1017/S1743921318001266

Phase analysis of solar activity indices using wavelet techniques

C. S. Seema and P. R. Prince

Department of Physics, University College, Thiruvananthapuram-695 034, Kerala, India
email: seemaniran@gmail.com, princerprasad@gmail.com

Abstract. A precise knowledge of solar extreme ultraviolet (EUV) irradiance is of great importance for better understanding of Earth′s ionosphere and thermosphere. The search for an ideal solar EUV proxy is vital since the ionospheric and thermospheric models are based on the solar proxies of EUV radiation. In this study, the phase asynchrony analysis of solar EUV data with other solar activity indices during solar cycle 23 is done. The cross-wavelet transform (XWT) technique is used to reveal the phase difference between the two time series of solar indices. Analysis reveals that the phase relationship between the indices is both time and frequency dependent. The solar indices F10.7 and Mg II core-to-wing index are found to be more synchronous with solar EUV data for low frequency components.

Keywords. Solar Index, cross-wavelet, solar cycle 23, etc.

1. Introduction

Ionospheric parameters are strongly controlled by solar activity, especially solar EUV flux since the production of ions in the F2 layer is mainly controlled by the Solar Extreme Ultraviolet (EUV) and X-ray radiations. All ionospheric models are based on solar EUV index-ionospheric relations. For improving the predictability of ionospheric models, the study of this relationship contributes much. Solar EUV data, Solar 10.7 cm radio noise (F10.7), Coronal Index, Mg II core-to-wing index and Sunspot number (R_Z) are some of the commonly used proxies for studying solar EUV activity(Kane 2002). F10.7 can be considered as a proxy of the Suns corona while the Mg II core-to-wing ratio measures solar chromospheric variability. Coronal index alarms physical processes taking place inside the Sun which are focused on solar magnetic fields whereas the Sunspot number concerns about the photosphere. As the solar EUV data is available since 1996 only, researchers are in search of a solar EUV proxy for long term analysis.

2. Data and Analysis

This study reveals the phase relationship of solar EUV index with other solar indices such as sunspot number (R_Z), 10.7 cm solar radio flux (F10.7), Mg II core-to-wing index and Green coronal index over 23rd solar cycle using cross wavelet techniques. The continuous wavelet does the convolution of time series x_n with the scaled and translated version of a normalized mother wavelet (Torrence & Compo 1998). A high wavelet power indicates the presence of significant time patterns (periodicities) at a particular time period. The common frequency features or phase difference of the two time series highlighting the temporal variations of their correlation is portrayed by Cross-wavelet power spectrum (Jevrejeva 2003).

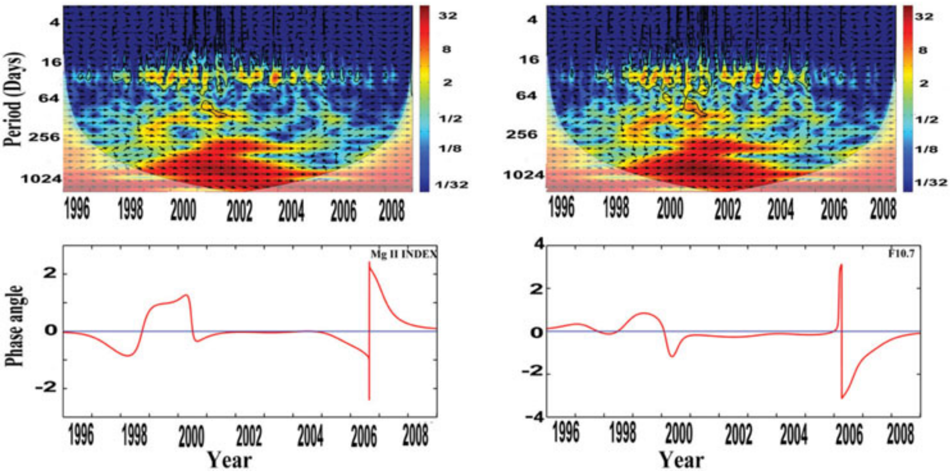

Figure 1. Cross-wavelet spectra of the solar indices [Mg II core-to-wing index (left), F10.7 (right)] with respect to solar EUV index. The relative phase difference of the indices with respect to solar EUV index for 1 year periodicity is also shown (down panel).

3. Results and conclusions

The relative phase difference between solar EUV and other indices- sunspot, Mg II core-to-wing index, F10.7 and coronal index done using the method of cross wavelet analysis. For all indices, the arrows at high frequencies are randomly distributed showing a strong phase mixing (Fig. 1). The time series is padded with sufficient zeroes to bring the total number of data points upto the next higher power of two. Due to this padding, the amplitude of power decreases near the edges and the cone of influence (COI) is the region at which the power drops by a factor e^{-2} and is shown in lighter shade below the thin curved line in Fig. 1. The arrows pointing right, indicate the in phase relationship and left arrows indicate the anti-phase relationship. The mean value of all phase angles corresponding to each period scales and their corresponding standard deviations were calculated throughout the entire cycle. The high values of standard deviations at high frequencies indicates strong phase mixing. The coherency cannot be indicated by this method since mean phase angle can approach zero with uneven phases. Choice of the appropriate period scale for studying phase differences affects the study of coherence between the two time series (Donner & Thiel 2007). The phase difference of each period scale is also plotted for the entire cycle for all the indices. The analysis of the phase angles plotted for all time period scales indicate that Mg II core to wing ratio and F10.7 indices show coherence with solar EUV at periodic scales of 1 year, 125 days and 27 days. Sunspot number shows coherence only for periodic scale of 125 days while coronal index shows the coherence for 1 year. The study reveals that F10.7 and Mg II index shows more coherence with solar EUV index than Sunspot number and Coronal Index.

References

Donner, R. & Thiel, M. ,1998 , *Astron. Astrophys.*, 475(3), L33
Jevrejeva, S. 2003, *J. Geophys. Res.*, 108(D21), 4677
Kane, R. P. 2002, *Ann.Geophys*, 20, 741.
Torrence, C. & Compo, G. P., 1998, *Bull. Am. Meteor. Soc.*, 79, 61