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Solar Wind Periodicities in 24 Solar Maximum

*Bidhu S S[1], Iren Sobia A[1], Dickson Benjamin[1]
[1]Department of Physics, Nesamony Memorial Christian College, Marthandam -629 165 India
Corresponding Author: Bidhu S S

Abstract: *Solar wind carries solar fluctuations to the magnetosphere as the result of solar rotations. In the present work, we use Morlet wavelet technique to investigate the periodicities of solar wind parameters during maximum phase of 24 solar cycle. The solar wind parameters utilized for wavelet analysis in this work are the interplanetary magnetic field, solar wind speed, temperature and density. ACE observations are compared with WIND observations to verify the periodicities during solar maximum. We found out that each parameter of the solar wind exhibit certain periodicities and time evolution of these periodicities in these parameters connected with the Sun's rotation. The short term periodicities are observed during 24 solar maximum due to higher solar activity.*
Keywords: *Solar Wind density, Solar Wind magnetic field, Solar Wind temperature, Solar Wind velocity, Wavelet Spectrum*

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I. Introduction

The solar atmosphere is not homogeneous and contains diffuse structures whose variable character is the basis of solar activity. Some of the variations are strictly periodic, especially those depending on solar or planetary motions. Whereas, others like solar cycle are only approximately periodic and phenomena like solar flares are aperiodic. Solar wind, being the continuation of solar corona, exhibits also periodic behaviour possibly be driven by the Sun periodic variations. Over the past, many studies have been made on the periodic or approximately periodic variations of the solar parameters like interplanetary parameters like IMF (Gonzalez and Gonzalez, 1987; Hapgood et al., 1991), solar wind velocity and plasma density (Mursula and Zieger, 1996), and plasma temperature. Different solar parameters exhibit different types of periodicities and these periodicities occur in different phases of the solar cycle. Some of the periodicities are common to all parameters and some others are found to evolve with the solar cycle

Recent helioseismic probing of the solar interior has shown that the rotation rate of the Sun near the base of its convective zone changes (Howe et al.2000). The differential rotation of the Sun is one of the main ingredients of the dynamo located at the base of the convection zone, which generates the magnetic field that is observed at the solar surface. Sun is a variable star that fluctuates and oscillates on various timescales ranging from seconds to several years. In particular solar activity rises and falls with the 11-year solar cycle, during solar maximum the Sun's magnetic field is predominantly toroidal, changing gradually during the declining phase to a poloidal structure (Solanki et al., 2006, Love et al., 2012). In addition, a gradual transition from solar maximum dominated by coronal mass ejection activity to solar minimum activities dominated by regions of open flux coronal holes takes place during this phase of the solar cycle. In a solar cycle, the dipole solar magnetic field also varies as minimum during solar maximum and maximum strength during solar minimum.

This work examines the periodicities of solar wind magnetic field, velocity,density and tempreratur e within the 2012-2014 interval which includes 24 solar maximum.. The time series examined exhibit a non-stationary, quasi-periodic behavior where periodic components appear intermittently and with varying significance levels. Solar cycles are characterized by changing recurrent geomagnetic activity which varies with the strength of the solar magnetic field and the emergence of sunspots. Currently when the new activity of the 24th solar cycle has in descending phase, it is a good occasion to discuss features of the whole 24 solar cycle maximum. Fortunately, nowadays measurements of solar activity and solar wind parameters are effectively measured by a large number of operating worldwide network of ground-based observatories and space probes.

The wavelet transform is a powerful tool for analyzing localized variations of power within a time series and is finding ever-widening astronomical and geophysical applications (e.g., Torrence & Compo 1998; Oliver et al. 1998; Fligge et al.1999). The wavelet transform decomposes a time series into time-frequency space, thus enabling the determination of the frequency spectrum of the variations as a function of space and time. Contrary to classical Fourier analysis that decomposes a signal into different sines and cosines which are not bounded in time, the wavelet transform uses wavelets characterized by scale (frequency) and position in time. It is therefore ideally suited for our present study.

II. Data And Method Of Analysis

The daily averaged values of solar wind velocity, density, interplanetary magnetic field components, and sunspot number are subjected to periodic analysis for 24 solar maximum. The solar and interplanetary data are obtained from the official website of ACE and OMNI dataset at CADWeb for WIND in electronic form. The data from Solar Wind Observations of the Magnetic Field Experiment (MAG) (C. Smith et al. 1998), the Solar Wind Electron Proton Alpha Monitor (SWEPAM) (D.J.McComas et al. 1998) for ACE and Solar Wind EXperiment (SWE) instrument and Magnetic Field Investigation (MFI) instrument for WIND are utilized for carrying out this work. Wavelet analysis is a powerful tool to decompose a time series into time-frequency space and to determine both the dominant modes of variability, in particular when these time series contain nonstationary power at different frequencies In this work, the Morlet wavelet (Morlet et al., 1982; Torrence and Compo, 1998) analysis was used because it is most adequate to detect variations in the periodicities of geophysical signals in a continuous way along time scales. In order to identify the time variation of non-stationary power contained at various periods, the solar and interplanetary parameters and geomagnetic activity index are subjected to wavelet analysis. It is possible to construct a picture showing the amplitude of any characteristics versus scale and how this amplitude varies with time (C. Torrence et al. 1998) by varying the wavelet scale and translating in time.

III. Wavelet Specrum Of Solar Wind Velocity

The wavelet spectrum of solar wind velocity in the period, 24 solar maximum is depicted in following figures. Fig:1 and 2 displays the wavelet spectrum of solar wind velocity in each period range and its evolution with time during 24 solar maximum for ACE and WIND respectively. The wavelet power shows higher power in a few selected periods.

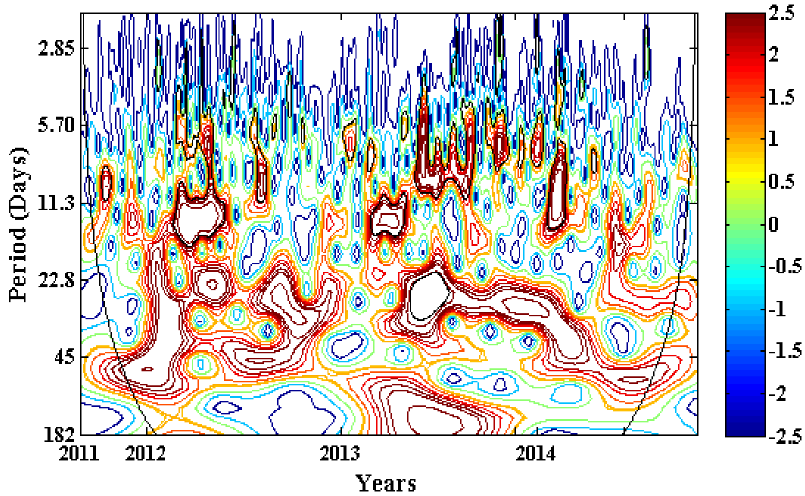


Figure: 1 shows the Wavelet spectrum of solar wind velocity for ACE spacecraft

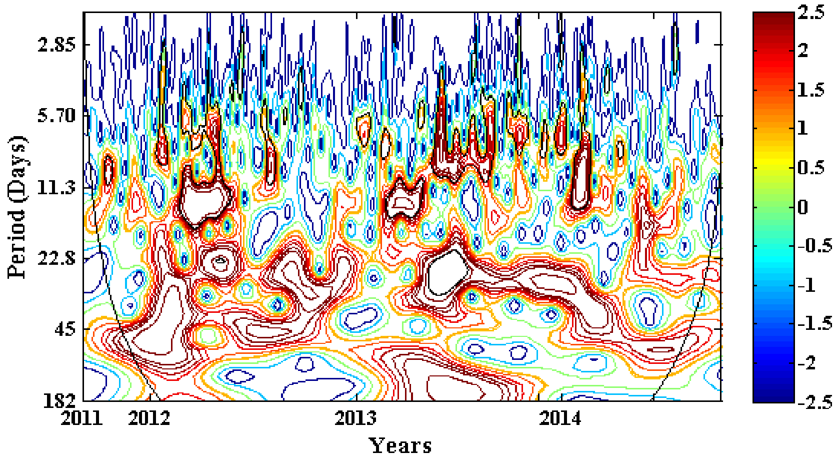


Figure: 2 shows the Wavelet spectrum of solar wind velocity for WIND spacecraft.

The solar maximum commencement period, 9 days of periodicities of solar wind velocity are observed by both spacecrafts. 9 days, 13.1 days and 27 days of periodicities are prominent during this solar maximum. 9 days of periodicities are striking features throughout the year 2013, but this periodicities are less pronounced in 2014 for both spacecrafts. 13.1 days of periodicities in 2012(March -May), and in 2013(February and March), and in 2014(February). WIND also measures 11.3 periodicities in the same periods as ACE observes. The amplitude of the 13.5 days period in velocity is strong and confined to a narrow band of periods. 27 days of periodicities are mainly notice 2012 and 2014.

IV. Wavelet Spectrum Of Solar Wind Density

The wavelet spectrum of solar wind density in the period, 24 solar maximum is depicted in following figures. Fig:3and 4 displays the wavelet spectrum of solar wind density in each period range and its evolution with time during 24 solar maximum for ACE and WIND respectively. The wavelet power shows higher power in a few selected periods.

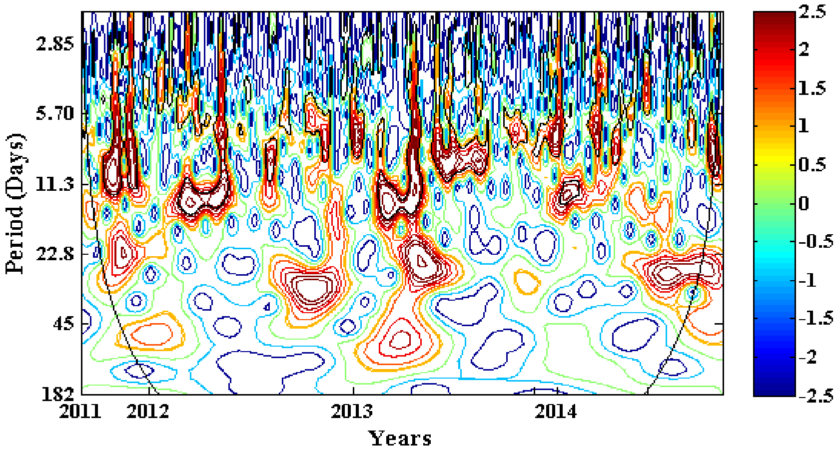


Figure: 3 shows the Wavelet spectrum of solar wind density for ACE spacecraft.

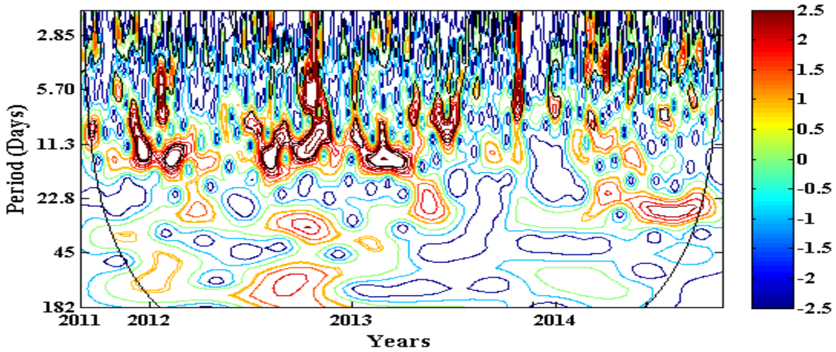


Figure : 4 shows the Wavelet spectrum of solar wind density for WIND spacecraft.

The evolution of wavelet power corresponding to the period of 24 solar maximum is depicted in above figures. 9 days, 13.1 days and 27 days of periodicities are present in 24 solar cycle maximum period. Among these, 13.1 days of periodicities is dominant one. 9 days of periodicities are more recorded by ACE than by WIND. 13.1 days of periodicities are present in beginning and ending of 2012, beginning of 2013, and this periodicities are absent during 2014 for WIND and for ACE, this periodicities are present in beginning of 2012 and 2013. WIND measured 27 days of periodicity only one time, ie; end of 2012. Both spacecrafts observed observed 27 days of periodicities in end of 2012, beginning of 2013 and end of 2014.

V. Wavelet Spectrum Of Solar Wind Temperature

The wavelet spectrum of solar wind temperature in the period, 24 solar cycle maximum is depicted in following figures. Fig: 5 and 6 displays the wavelet spectrum of solar wind temperature in each period range and its evolution with time during 24 solar maximum for ACE and WIND respectively. The wavelet power shows higher power in a few selected periods.

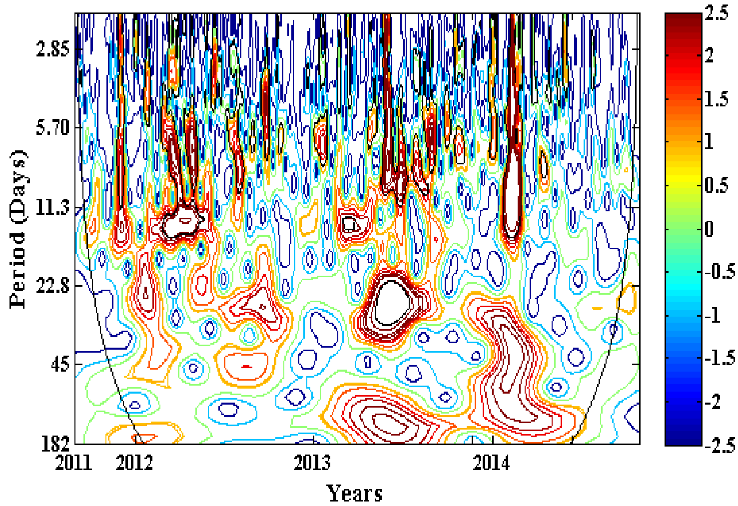


Figure: 5 shows the Wavelet spectrum of solar wind temperature for ACE spacecraft.

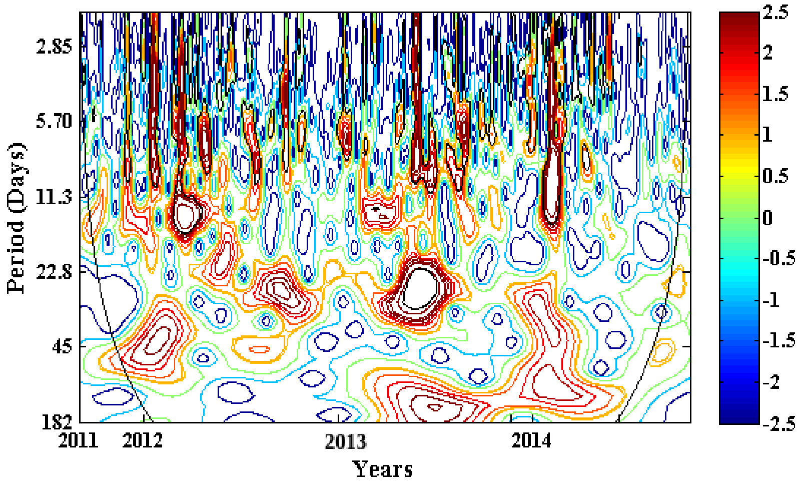


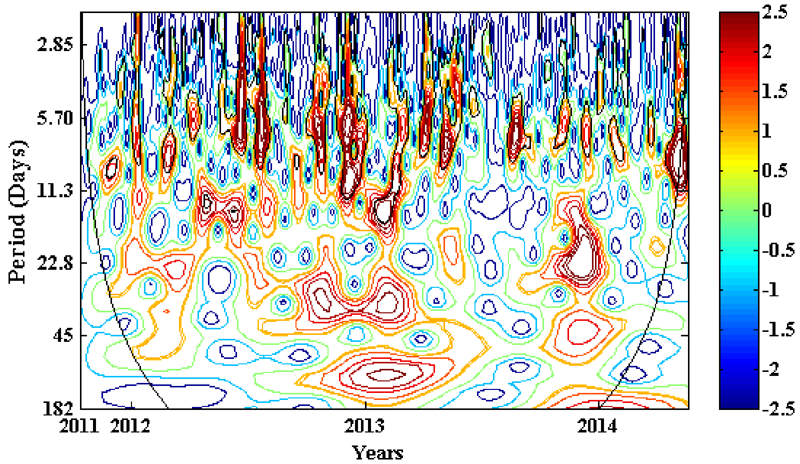
Figure: 6 shows the Wavelet spectrum of solar wind temperature for WIND spacecraft.

The wavelet spectrum of solar wind temperature show 27 days and 13.1 days of prominent periodicities during 24 solar maximum. In maximum phase stronger periods are mainly concentrate at shorter periods, mainly less than solar rotation periods. Onset of solar maximum contains shorter periods less than 27 days. 27 days of periods are found in middle of 2013 by both spacecraft, 13.1 days of periodicities are present in 2012 and 2014. Wavelet spectrum of solar wind temperature for ACE and WIND for periods, greater than 50 days show homogeneity pattern. It is observed that strength of periodicity is maximum in 2013 and minimum in 2012 for ACE and WIND.

VI. Wavelet Spectrum Of Solar Wind Magnetic Field

The wavelet spectrum of solar wind temperature in the period, 24 solar maximum is depicted in following figures. Fig: 7 and 8 displays the wavelet spectrum of solar wind temperature in each period range and its evolution with time during 24 solar maximum for ACE and WIND respectively. The wavelet power shows higher power in a few selected periods.

Figure: 7 shows the Wavelet specrum of solar wind magnetic field for ACE spacecraft.



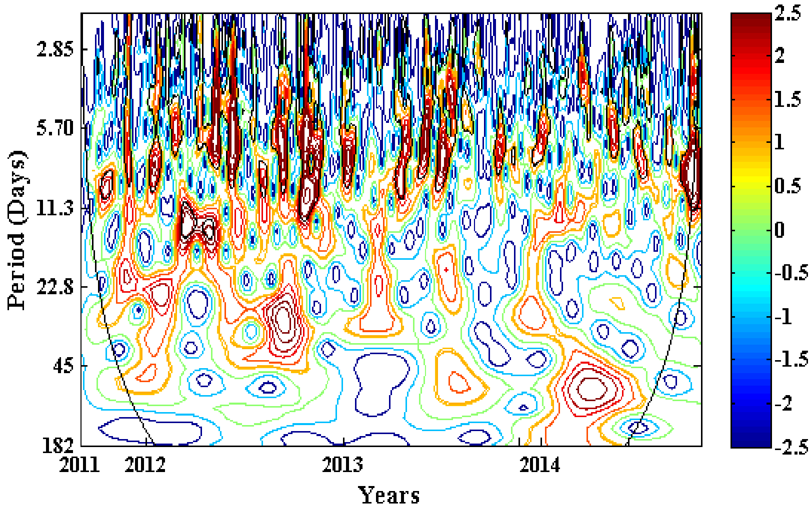


Figure: 8 shows the Wavelet spectrum of solar wind magnetic field for WIND spacecraft.

The wavelet spectrum of solar wind magnetic field show 27 days, 13.1 days and 9 days of prominent periodicities during 24 solar maximum. ACE observe stronger periods at 2013 and 2014 for 13.1 days of periodicities. But WIND observe 13.1 days of periodicities in 2012 and 2014. 27 days of periodicities are present in end of 2012 and beginning of 2013 for ACE whereas it is present only in middle of 2012 for WIND. The wavelet spectrum of magnetic field for ACE and WIND spacecrafts are not follows the same pattern of periodicity during this solar maximum.

VII. Result And Discussion

The observations of ACE and WIND recorded 8 days, 13.1 days, 27 days and more than 50 days periodicities for solar wind parameters. In active phase, when the Sun is nearing the maximum phase with complicated sunspots,the 13.5 period is found. (Pap et al., 1990). The 13.5 day period in the solar wind velocity during the maximum phase of the solar cycle is due to the presence of two stream structure associated with the two sector structure of the IMF. The coronal holes are sources of low solar wind density. So the features associated with the periodicities of solar wind velocity are applicable to the solar wind density also. During solar maximum, the solar magnetic field has dipolar as well as non-dipolar (quadrupole components) components (Wang, 1993). The relative strength of dipolar and non-dipolar components decides the large scale feature of the solar magnetic field and hence the IMF. The 13.5 day period of the IMF magnitude is evidently due to the dipolar nature of the solar magnetic field. The occurrence and relative power of the 13.5 day periodicity of the magnitude of IMF has somewhat different distribution over the solar cycle than solar wind velocity or density attaining more power around the sunspot maximum times (Mursula and Zieger, 1996). The IMF will have more sectors during these periods. This may be the reason for the enhancement of 8-day periodicity in IMF magnitude and its components during the maximum phase of the solar cycle.

The 27 day recurrent geomagnetic activity is prominent during the 24 solar maximum. The 27-day periodicity is an important factor in the prediction of the daily levels of geomagnetic activity. When the pattern is strong, the prediction is more reliable (Hapgood, 1993). It has long been accepted that 27 day recurrent geomagnetic activity is caused by the interaction between the Earth's magnetosphere and high speed solar wind streams which co-rotate with the Sun (Wilcox and Ness, 1965). The periods 53 days and above gives the indication of flare index or other solar transients. During maximum phase, these higher periods are dominant in eccliptic region. The origin of the periods like more than 53 days may be associated with activity of concentrated magnetic fields typical of sunspots, but not associated the more spread field regions (Ozguc and Atac, 1994).

VIII. Conclusion

Several interesting features regarding the behavior of the Sun have been revealed by this wavelet spectrum analysis of solar wind parameters during 24 solar maximum as observed by ACE and WIND. The solar surface and interplanetary medium parameters exhibit different types of periodicities and the amplitude of these periods vary with the phase of the solar cycle. The Morlet wavelet spectral methods are used to identify the significant periods in the spectrum of solar wind velocity and density, temperature and magnetic field data observed during 24 solar maximum.The main periodicities in a time series are identified by the wavelet-transform and it is also used to study the time evolution of each period. The wavelet power spectrum of solar wind velocity,density and temperature shows same pattern for both spacecrafts observations whereas wavelet spectrum of solar magnetic field of are not like for ACE and WIND observations. Some of these periodicities like 13.1 day, 27 day are common to all parameters during this period. The solar wind number density, IMF do not show any systematic amplitude evolution in the 0-50 day period range.

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