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# THE 1.3-YEAR VARIATION IN SOLAR WIND SPEED AND GEOMAGNETIC ACTIVITY

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## ABSTRACT

Recent studies have discovered a strong 1.3-year variation in solar wind speed. It has been shown that this variation occurs concurrently at different heliocentric distances around the ecliptic. The same periodicity has also been observed in geomagnetic activity and occurrence of aurorae which are greatly dependent on solar wind speed. We study this periodicity using solar wind speed measurements at 1 AU from 1964 onward, and the Kp index of geomagnetic activity from 1932 onward. We show that the 1.3-year variation is a quasi-periodicity which occurs during even solar cycles. On the other hand, during odd cycles, we find a somewhat longer periodicity with a period varying from 1.5-1.7 years. Both of these periodicities are expected to be due to the evolution of coronal holes. Therefore, the observed difference in period implies a difference in the evolution of coronal holes during even and odd cycles. 

## INTRODUCTION

A few years ago, Richardson *et al.* (1994) noted on a new strong periodicity in solar wind (SW) speed with a period of about 1.3 years. The SW speeds showed variations with an amplitude of about 100 km/s which dominated the SW speed time series from 1987 onwards. They also compared the SW speeds at 1 AU and in the outer heliosphere using Voyager 2 data to show that very similar fluctuations are observed at both heliocentric distances. They speculated that this periodicity might be related to the topology of coronal holes and to the formation of open magnetic structures.

Gazis *et al.* (1995) extended the analysis using data from additional spacecraft, and verified that the 1.3-year periodicity was dominating the heliosphere after 1987 from inner heliosphere (Venus orbit at 0.72 AU) to outer heliosphere (almost 60 AU). They concluded that these variations must originate quite close to the Sun, probably in the SW source region. Later, Gazis (1996) showed that the SW speed enhancements responsible for the 1.3-year variation do not arise from the merging of structures during SW evolution. Moreover, they found that the long-term correlations between the SW parameters during these enhancements suggest a solar origin for the 1.3-year periodicity. Szabo *et al.* (1995) discovered the 1.3-year variation in the north-south component of the interplanetary magnetic field simultaneously with the SW speed. Several authors have earlier shown that related periodicities exist in geomagnetic activity (e.g. Shapiro, 1967; Fraser-Smith, 1972; Delouis and Mayaud, 1975) and auroral activity (Silverman and Shapiro, 1983) at varying level of significance at different times. Paularena *et al.* (1995) showed that the 1.3-year periodicity occurs coincidently in SW speed and geomagnetic activity after 1987.

## DATA AND METHOD

We use here the SW speed data included in the OMNI data set (http://nssdc.gsfc.nasa.gov/omniweb), and the Kp index as a measure of geomagnetic activity. We averaged the hourly SW speed data and the 3-hourly Kp indices to 10-day averages, and made a linear interpolation over the remaining data gaps in SW speed. A bandpass convolution filter (boxcar tapered with Hanning window) was repeatedly applied to these data to extract their long-term variation. Fig. 1 depicts the filter for a central period of one year in the time domain (impulse response functions of the in-phase and out-of-phase filters) and frequency domain (transfer function). The filter has a pass band width of ±5% of the central period. As seen in Fig. 1, the filter attenuates periods outside 10% of the central period by

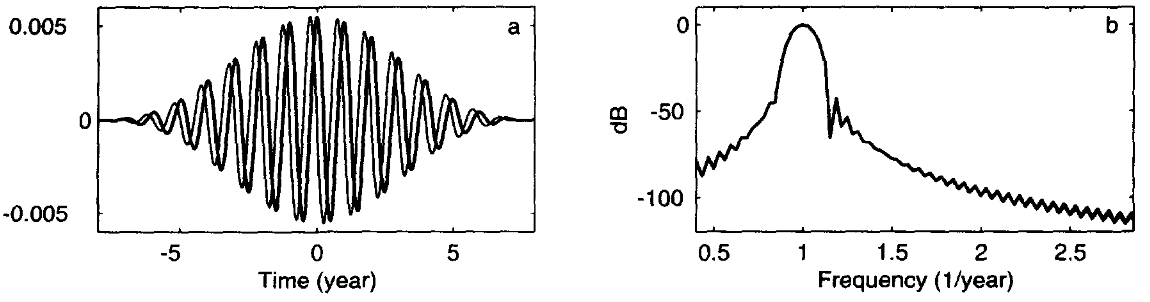


Fig. 1. In-phase (thick line) and out-of-phase (thin line) bandpass filters for a central period of one year in (a) time domain and (b) frequency domain.

about 15 dB. The half-width length of the 1-year filter (effective time resolution) is about 6-7 years. Varying the central period of the filter in steps of 5%, we covered the period range from 0.35-2.5 years. The amplitudes were calculated from the in-phase (real part of the complex wave vector) and out-of-phase (imaginary part) signals for each data point. Moreover, the amplitudes were normalised by the mean amplitude in the 0.35-2.5-year period range to allow intercomparison between the two parameters. These relative amplitudes were then plotted as an intensity diagram with time and period, producing a kind of dynamic spectrum.

## RESULTS

Fig. 2 shows the dynamic spectra for SW speed and Kp index. The two parameters depict a fairly similar pattern of periodicities over the common interval. In particular, the strong enhancement at T=1.3 years from late 1980's until mid-1990's is clearly visible. The 1-year variation (see e.g. Zieger and Mursula, 1998) is seen around solar minima. There is also a common periodicity at about 1.6-1.7 years in both parameters in early 1980's. This periodicity was recently discovered in cosmic rays (Valdés-Galicia *et al.*, 1996). At periods below one year, both parameters have a strong enhancement at about T=0.7 years in late 1980's, and a weaker in late 1970's. This periodicity has been found in

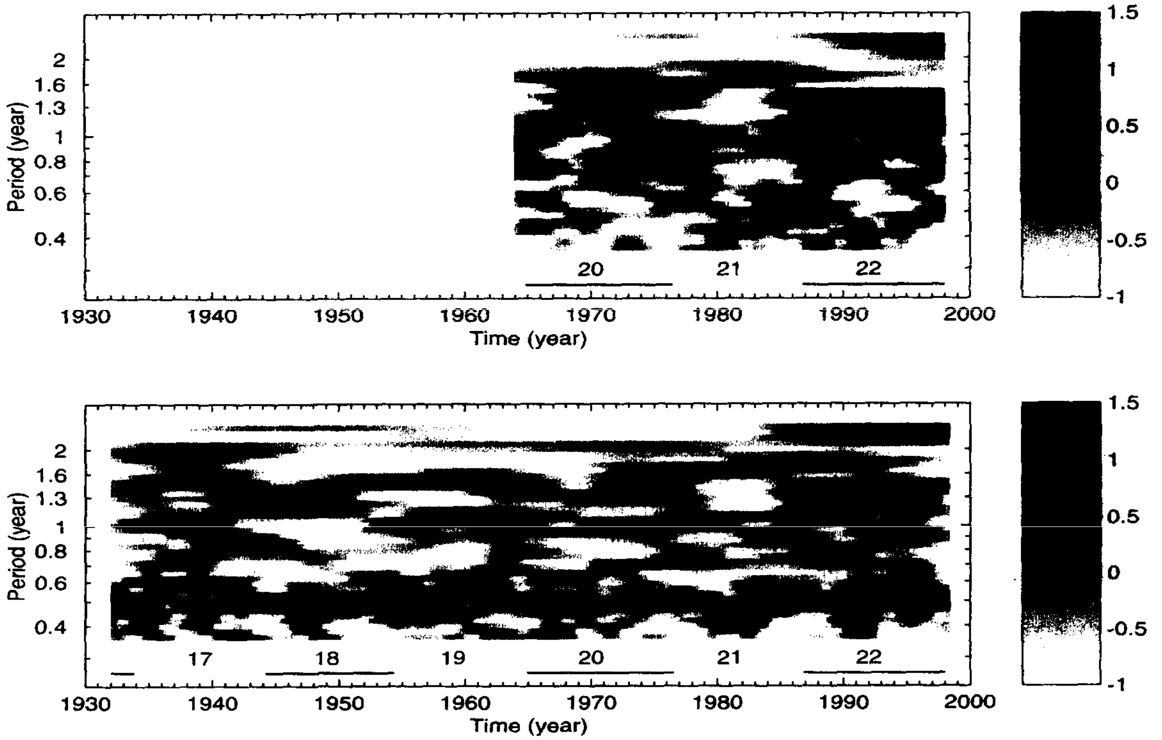


Fig. 2. Dynamic spectra of SW speed (top) and Kp index (bottom) constructed from the amplitudes of filtered data. Logarithmic color scale at right is given in powers of two.

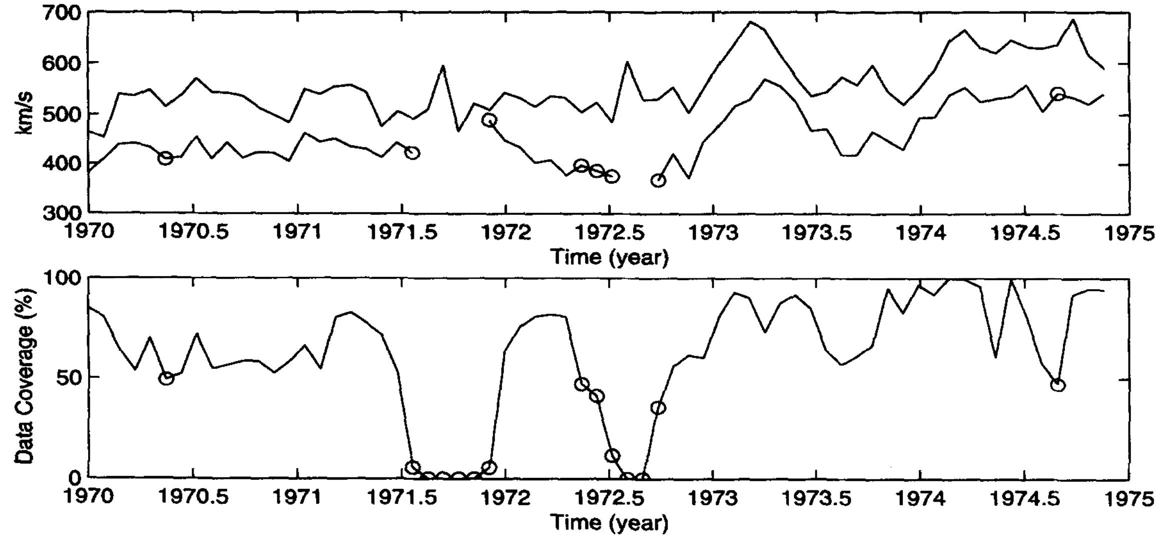


Fig. 3. Top: 27-day averaged Kp index and SW speed (scale for SW speed). Bottom: SW speed data coverage in percentage of hourly values. Circled points have less than 50% coverage.

several solar parameters (see e.g. Pap *et al.*, 1990). Kp shows the well-known strong 0.5-year variation (Russell and McPherron, 1973), persisting over the whole time interval studied. There is also a significant 0.5-year variation in SW speed in mid-1980's (Zieger and Mursula, 1998). In early 1980's there is a strong enhancement at about 0.4 years which is also observed in sunspots and solar flares (see e.g. Oliver *et al.*, 1998).

However, in early 1970's the two parameters seem to behave somewhat differently. While the SW speed shows a strong, broad enhancement around T=1.5 years, Kp has an enhancement at about 1.3 years. We have studied this difference in more detail. Fig. 3 shows the 27-day averages of SW speed and Kp index as well as the percentual coverage of SW data in 1970-74. The circles denote points with less than 50 % data coverage. There are two long data gaps in SW speed, one in 1971 and the other in 1972. These gaps disturb the similarity of the wave form of the two variables in Fig. 3, and cause the difference between the dynamic spectra in Fig. 2. The first SW speed data point after the gap in 1971 disagrees considerably with the value expected from the Kp index. This data point has a very small data coverage of 6% only. Interpolating the SW speed data over this gap introduces a spurious peak. Moreover, due to the data gaps, the two peaks in Kp in late 1971 and 1972 are missed in SW speed. Accordingly, these two data gaps considerably affect the long-term periodicities of SW speed in early 1970's resulting in spurious enhancements at this time (e.g. at about 1.5 years and 0.6 years). Therefore, we regard the Kp index as more reliable during this time.

## DISCUSSION

The pass band width of the filter used in the present paper was selected in order to achieve a reasonably high frequency resolution, allowing us to separate the different periodicities to an accuracy of $\pm 5$ %. The high frequency resolution results in a smaller time resolution of about 3-10 years in the period range covered. However, since this is less than a typical solar cycle length, we can locate the times of occurrence of the different periodicities to a particular solar cycle. (Moreover, we have used a filter with $\pm 10\%$ pass band width to increase time resolution. These results are not shown here).

As seen in Fig. 2, the 1.3-year periodicity is found to exist in three different time intervals in geomagnetic activity. The strongest 1.3-year variation occurred during the solar cycle 22. A weaker 1.3-periodicity existed in early 1970's in SC 20. Another strong enhancement of 1.3-year variation was found in mid-1940's in the ascending phase of SC 18, as earlier noted by Paularena *et al.* (1995). Accordingly, the 1.3-year variation seems to occur mainly during even solar cycles and, therefore, depicts a roughly 22-year variation. We have verified the significance of the 1.3-year variation in the 5-year intervals 1943-47, 1970-74 and 1989-94 (times of maximum amplitudes) using the Stellingwerf (1978) method.

Moreover, we can see in Fig. 2 that during odd cycles a periodicity existed in geomagnetic activity which consistently had a somewhat longer period than 1.3 years. During SC 21 this period was 1.6-1.7 years. In SC 19 the period was slightly shorter of about 1.5 years and in SC 17 about 1.6 years. These periodicities were found to be significant in the 5-year intervals of 1935-1939, 1953-57, and 1978-82, respectively. Accordingly, this periodicity seems to be related to odd solar cycles, thus depicting a quasi-22-year variation similar to the 1.3-year periodicity. We would like to note that the 1.6-1.7-year periodicity has not been reported earlier in SW speed although it is known e.g. in cosmic rays (Valdés-Galicia *et al.*, 1996). Moreover, McIntosh *et al.* (1992) observed the 1.6-1.7-year periodicity in coronal hole area during SC 21.

Concluding, we find that the 1.3-year variation is a quasi-periodicity which occurs during even solar cycles. In the time interval measured by the Kp index, cycle 22 had the strongest 1.3-year intensity. Also, we find a new periodicity in solar wind speed and geomagnetic activity with a longer period of about 1.5-1.7 years which exists during odd solar cycles. This pattern of alternating periodicities seems to be systematic and, therefore, implies a new fundamental difference between even and odd solar cycles. Moreover, since these periodicities most probably arise from the behaviour of coronal holes, our results suggest that the coronal holes develop systematically differently during even and odd solar cycles.

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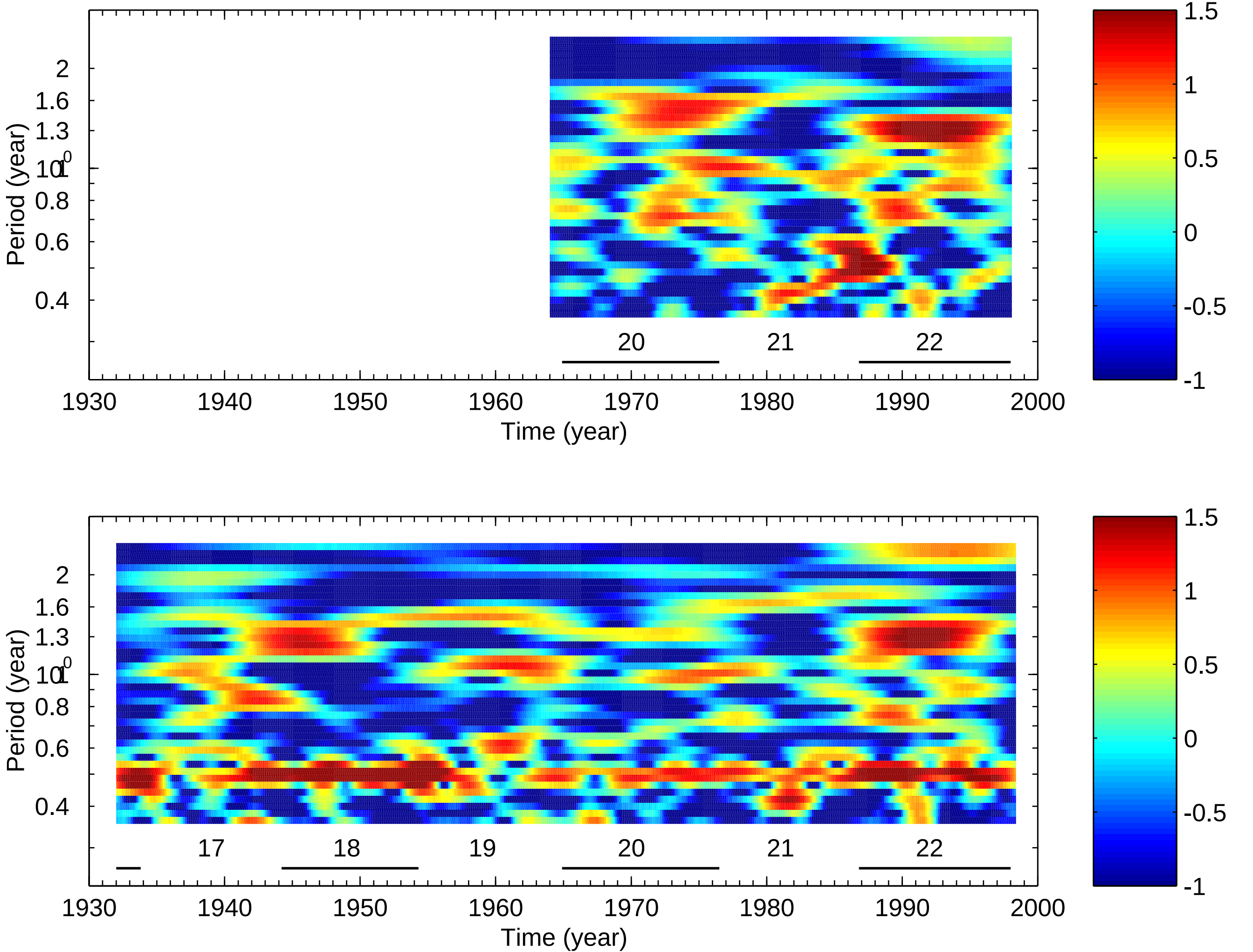

Period (year)
Time (year)
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