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Usability of solar radius variations as an indicator of solar activity and influence on climate

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Abstract. In this study we investigated whether the solar semi-diameter could be treated as an indicator of solar activity. We applied the cross-correlation method to show the agreement of solar radius data with solar irradiance measurements. We used the solar semi-diameter data obtained from astrolabe observations at TUBITAK National Observatory (TUG) / Turkey and at Cote d′Azur Observatory (OCA)/France. We treated the regional air surface temperature measured in Antalya/Turkey as a climate indicator. Result of our analyses, indicates a considerable correlation (-0.63) between the solar radius and solar irradiance measurements. In addition, a comparison of solar radius and regional temperature values indicated that there is an acceptable correlative and periodical agreement between the two quantities.

Key words. solar activity, solar radius, surface temperature, sun and climate periodicities

1. Introduction

To show usability of the solar radius measurements as a solar activity indicator, the solar radius measurements are compared with VIRGO solar irradiance. It is well known that, solar radiation output is not constant and it shows cyclic changes; this change can be seen in many solar activity indicators such as sunspot numbers, sunspot areas, etc.. Solar radius measurements made by astrolabe and total solar irradiance data have been available only since 1978. To show solar activity change; solar irradiance is a good indicator, but for the solar radius there is not any decision whether it can be used as a solar activity indicator because there are contradictory results: while in some investigations a negative correlation was obtained (Laclare et al. 1996; Pap et al. 2001), Rozelot (1998), and Noël (2004) have reported that, the two phenomena show positive correlation. The other idea is that there is not any correlation (Wittman 2003; Kuhn et al. 2004).

Astrometric observations of the Sun at TUG astrolabe station with the solar astrolabe were begun in 1999. The observations have been made with three reflecting prisms at 30^o, 45^o, and 60^o fixed zenith distances. The first results of these observations, which covered the period from 1999 to 2001, and the technical information relating to the instrument have been already published elsewhere (Golbasi et al. 2001).

The effect of the solar activity on the Earths climate is not clear because of the many parameters involved and change in the atmospheric composition since the beginning of industrial revolution. Santer et al (1996), Wigley et al (1997) and others claim that solar forcing and

Table 1. Change of the VIRGO solar irradiance and TUG solar radius measurements. Vertical axis is in arbitrary unit.

	N.D	Mean ()	Std Dev.()
D.M	2304	959.31±0.01	0.32
N.D	795	959.30±0.01	0.23

anthropogenic forcing; together are enough to explain the overall warming trend. Another point due to Crowley (2000) is that the Earth climate system had been controlled by the Sun before the pre-industrial era, but later anthropogenic effects began to dominate.

2. Data and Analysis

In this study, we used VIRGO solar irradiance measurements, taken from SOHO web page, as a solar activity indicator. Monthly and daily values were calculated from measurements. To reveal usability of solar radius measurements as a solar activity indicator calculated daily and monthly values were used. To investigate sun-climate interaction, monthly values of OCA solar radius data and composite solar irradiance taken from NGDC have been used.

Three step running average smoothing method was applied to both of monthly data sets. Correlation coefficient calculated from these smoothed data by the use of cross-correlation method. Our results indicate a considerable negative correlation, with correlation coefficients of -0.63, between the smoothed monthly VIRGO solar irradiance and TUG solar radius data for the period from 2001 to 2004. Relation of the parameters to each other are shown in Figure 1.

In addition, we have calculated correlation coefficient between yearly temperature and solar radius data for the investigated time period (1978 - 2000). We applied 9 steps running average smoothing method to both monthly data, thus we obtained about yearly values. We found that, while the temperature and solar radius shows a correlation of -0.45 before 1990, for the investigated whole period there is no correlation, it is -0.14.

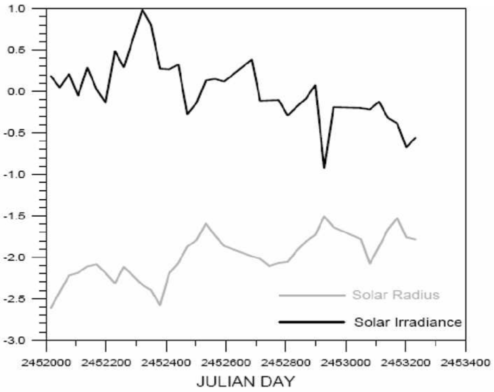

Fig. 1. Change of the VIRGO solar irradiance and TUG solar radius measurements. Vertical axis is in arbitrary unit.

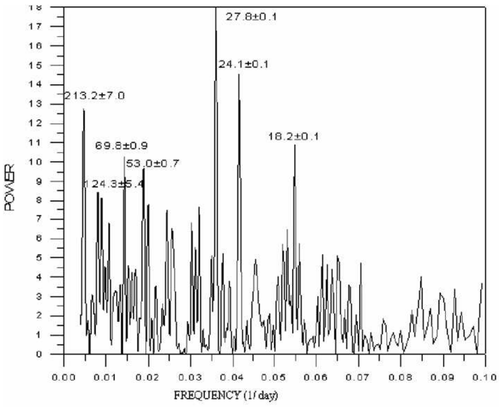

Fig. 2. TUG daily solar radius data power spectrum. The errors of the periods are obtained using the clean software developed by Foster (1995).

On the other hand it is well known that the solar activity exhibits short-term cyclic trends such as 27-day, 24-day, 154-day periodicities etc.. To investigate the periodicity, we have used the Fourier analysis technique Scargle periodogram (Scargle 1982) applied to the smoothed daily mean solar radius data. We investigated only periodicities that are between 10 and 250 days due to the lack of the measurements from November to second part of February for each year. Periods obtained in our analysis are shown in Figure 2.

Table 2. Comparisons of periodicities extracted from TUG solar radius observations (our results) and corresponding periodicities in the literature (literature).

our results	literature	Sources	Authors
24±0.1	24	solar flares	Temmer et al. (2004)
	24.5	solar radius	Penna et al. (2002)
	25.5	solar flares	Bai (2003)
213±7	200	sunspot areas	Sello (2003)
	220	sunpot areas	Sello (2003)
	180	solar radius	Penna et al. (2002)
18.2±0.1	21±1	solar flares	Mavromichalaki et al. (2003)
	18±2	cosmic rays	Mavromichalaki et al. (2003)
69±0.9	73	solar flares	Ozguc and Atac (1994)
	78	solar flares	Bogart and Bai (1985)
	70	solar flares	Mavromichalaki et al. (2003)
53±0.7	51	solar flares	Bai (1987)
	51	sunspot areas	Pap et al. (1990)
124±5	127	solar flares	Bai and Sturrock (1991)
	129	flares	Bai (2003)
111±3	108	solar radius	Penna et al. (2002)
31±0.3	32±1	solar flares	Mavromichalaki et al. (2003)
	31.8	solar radius	Penna et al. (2002)
	33.5	solar flares	Bai (2003)
41±0.4	35±5	solar flares	Mavromichalaki et al. (2003)
93±2	105	solar flares	Mavromichalaki et al. (2003)

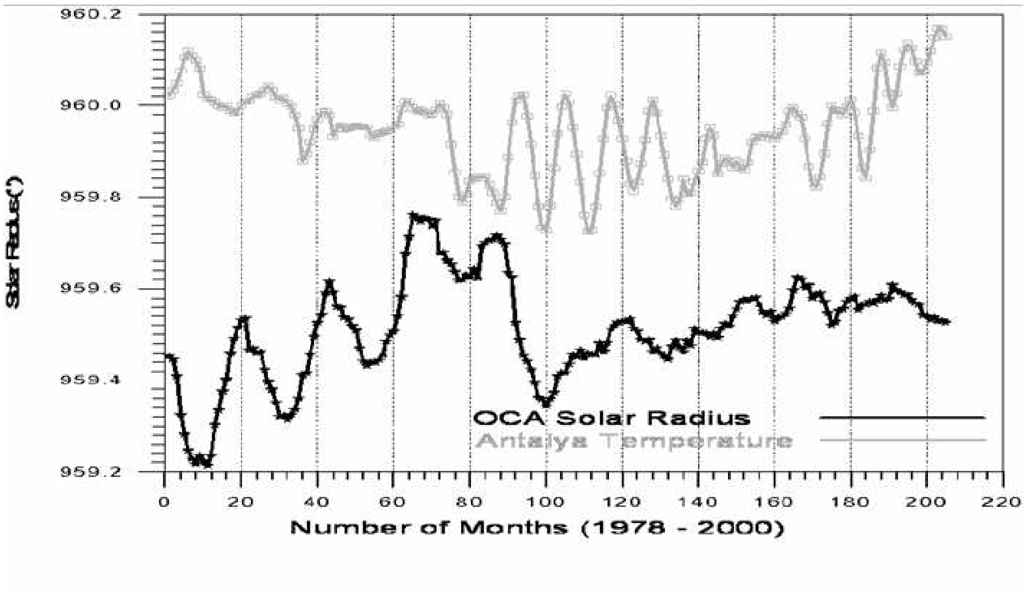

Fig. 3. Change of the solar radius and Antalya surface temperature. Temperature on vertical axis is rescaled so as show them in same graph.

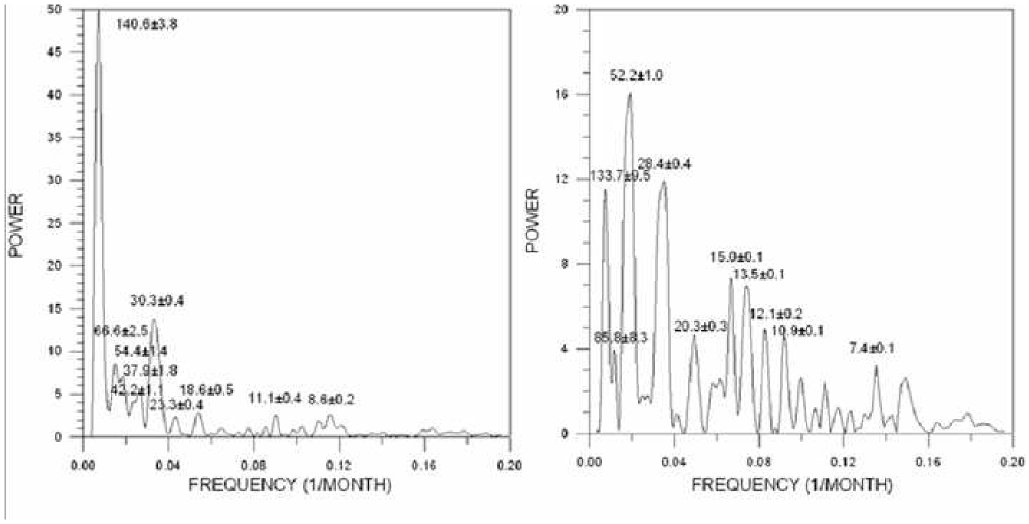

Fig. 4. Power spectrum of monthly solar radius measurements and Antalya surface temperature, respectively.

Also we applied period analysis to both 9 step smoothed monthly data; we found that some fundamental periods for both parameters are similar. Power spectrum of both parameters is given in Figure 4.

3. Discussion

Several solar activity indicators have been used in the literature up to now. In this study we discussed usability of solar radius measurements as a solar activity indicator. For this, we used solar radius data obtained from TUG astrolabe observation site. We found 63-percent negative correlations between two data. Also agreement of both parameters to each other can be seen from Figure 1.

In addition to this, we applied Fourier period analysis to both daily data. We detected 27.8-day period as the best determined periodicity. Its well known that this is equal to solar rotation period. The other periods obtained in our study are given in Table 2.

Many researchers studied periodicities in sunspot areas and numbers were determined near 154 days periodicity during cycles 19 - 21 (Oliver et al. 1998; Krivova and Solanki 2002), cycle 2 (Ballester et al. 1999); cycles 16 - 18 (Carbonell and Ballester 1992; Oliver et al. 1998), but not cycles 12 - 15 (Carbonell and Ballester 1992). In our study, we detected this period with modest power value for the investigated time period; this contradictory result may arise from gap of the data, measurements error and so on. In addition to these, Bai (2003) noted that 51, 78, 127, and 153-day periods were very close to integral multiples of 25.8 day periods. On the other hand 24, 31 and 33-day periodicities obtained in our study may be attributed to solar rotation.

If all of these results are considered together, they may indicate that the solar radius measurements may be used as a solar activity indicator. However existence of contradictory results and lack of longer-term radius measurements make the results doubtful.

To show sun-climate interaction, monthly OCA solar radius and Antalya surface temperature data were used. The discordant results obtained in correlation analysis may arise from measurements technique of both parameters or change of the regional atmospheric composition. In the result of Fourier period analysis; it is interesting that, both parameters show about 11 year period as an important periodicity. Similarly some other important periods obtained from solar radius data also agrees with Antalya surface temperature data. These are 54.4, 30.3 and 11.1-month. From these results we may say that solar activity has an effect on regional climate but its effect may be suppressed by other factors.

4. Conclusion

In this study, we considered using possibility of the solar radius measurements as a solar activity indicator. The solar radius measurement made at TUG astrolabe station show periodicities similar to other solar activity indicators. On the other hand we obtain rather high negative correlation (-0.63) between solar radius and VIRGO solar irradiance measurements period from 2001 to 2004. In spite of the lack of long term radius measurements, our results indicate that the solar radius measurement may be used as a solar activity indicator. But we need to longer-term solar radius data for more reliability.

Also we investigated solar radius and regional temperature changes: for this we compared Antalya monthly mean surface temperature and OCA solar radius measurements and we found that two parameters show acceptable negative correlation period from 1978 to 1990, but we didn′t detect any correlation between two parameters in time interval investigated in this study. Also we applied period analysis to both 9 steps running average monthly data and we obtained that two parameters show some important similar periodicities. We may say that the solar activity affects the Earths climate.

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