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Quiet-Sun Variability with the Solar Cycle

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Abstract. In evaluating the contribution of various chromospheric features to total CaII K-emission flux and UV irradiance variability, the quiet-Sun is also one of the essential and important component. We have segregated the disc center intensity in a quiet-network and intranetwork regions, considered as a quiet-Sun component, from a digitized CaII K-spectroheliograms of 1992 and 1980, observed at the National Solar Observatory at Sacramento Peak. It is shown, *for the first time in the K-line*, that the longer-term variation of the quiet-Sun during the solar activity cycle is in phase with the full-disk K-emission flux (the spatial K index), and UV irradiance measured in MgII h and k lines. Thus, it indicates that the quiet-Sun will contribute in the variations of UV irradiance, and its contribution should be taken into account in UV irradiance models.

Using a standard FFT time series analysis, our results show, *for the first time*, the 51-day periodicity in the quiet-Sun variability. This evidence suggests that the 51-day period may be related to a new emerging weak magnetic fields, and the emission flux disappearance continues in the quiet-Sun regions at a slower rate. In addition, the variability of the chromospheric quiet-Sun suggest that it is very dynamic, *not quiet*, and is crucial for understanding of the chromosphere itself.

1. Introduction

Determining the contribution of the various chromospheric features to changes in UV irradiance is one of the main principal concerns for improving the current UV irradiance models and hence for both climatic and solar physics studies, since the solar radiative output is the main driver of the physical processes within the Earth's atmosphere. Thus the monitoring and study of the changes in UV irradiance are extremely important. The long-term irradiance variations are attributed to the changing emission of bright magnetic elements (Foukal & Lean 1988), and the short-term irradiance variations are directly associated with active regions as they evolve and move across the solar disk (Lean 1987). The current irradiance models are based on full-disk surrogates, therefore they cannot provide adequate information on the physical mechanisms of solar irradiance variability, detailed analysis of spatially resolved data is essential. The quantitative estimation of contribution of individual chromospheric features to UV irradiance variability is still an unexplained problem in solar physics.

The CaII H and K resonance lines are good indicators for identifying regions of chromospheric activity and for structural changes related to solar magnetic activity. A two-dimensional image of the Sun (spectroheliogram) in the CaII H or K line under high spatial resolution shows that the three agencies responsible for CaII emission are: (i) plages, (ii) the network elements, and (iii) the intranetwork elements. The changes in the network and intranetwork elements related to solar activity are less understood, especially because of the lack of systematic and quantitative measurements of these chromospheric features. Therefore, detailed analysis of the chromospheric fine structure is crucial for understanding the underlying physical mechanism of solar irradiance variability and to determine the contribution of the above-listed structures to the changes in UV irradiance (Sofia, Oster, & Schatten 1982; Lean et al. 1982; Kariyappa & Sivaraman 1994; Kariyappa & Pap 1996, henceforth Paper I) , and to incorporate the results into the irradiance models. It should be noted that one of the largest problems in analyzing the images of the Sun is the selection of the quiet-Sun regions which are used to normalize the final values of the full-disk indices. The contribution of quiet-Sun variability to the changes in solar UV irradiance is unresolved and its variability as function of solar magnetic activity is an unexplained problem in solar physics.

In our previous Paper I, we have presented the results on a new method of analysis of CaII K-spectroheliograms, and the variation of chromospheric features for the time interval of 1992 and 1980. Our aim in this paper is to separate and examine the variability and importance of the quiet-Sun with the solar cycle.

2. Observations

In our earlier Paper I, we have discussed the observational details of CaII K spectroheliograms of National Solar Observatory at Sacramento Peak (NSO/Sac Peak). We have selected and digitized about 1500 daily spectroheliograms for a 6-year-long time interval, when each year represents a different phase of the solar cycle, namely 1980 (maximum of SC21), 1985 (minimum of SC21), 1987 (the beginning of the ascending phase of SC22), 1988 and 1989 (ascending phase and maximum of SC22), and 1992 (descending phase of SC22). We have described the reduction procedure in great detail in our previous Paper I.

In the present paper, we have used 424 images for the time interval of 1980 and 1992 and extracted the disc center intensity in a very quiet regions covering the area of 36 arcsec x 36 arcsec on the Sun. Further data handling will also be described below, together with the results.

3. Results and Discussions

The solar chromosphere is highly structured by the emission features; the variability of these chromospheric emission features is the primary modulator of the solar UV irradiance on time scales of hours to years. To better understand the physical process and nature of the solar UV irradiance variations, it is important to know the spatial and temporal character and evolution of the chromospheric emission features including the background chromosphere and the quiet-Sun.

In order to understand and clarify the variability of quiet-Sun, we have extracted a quiet-Sun component at the center of the solar disc from 424 CaII

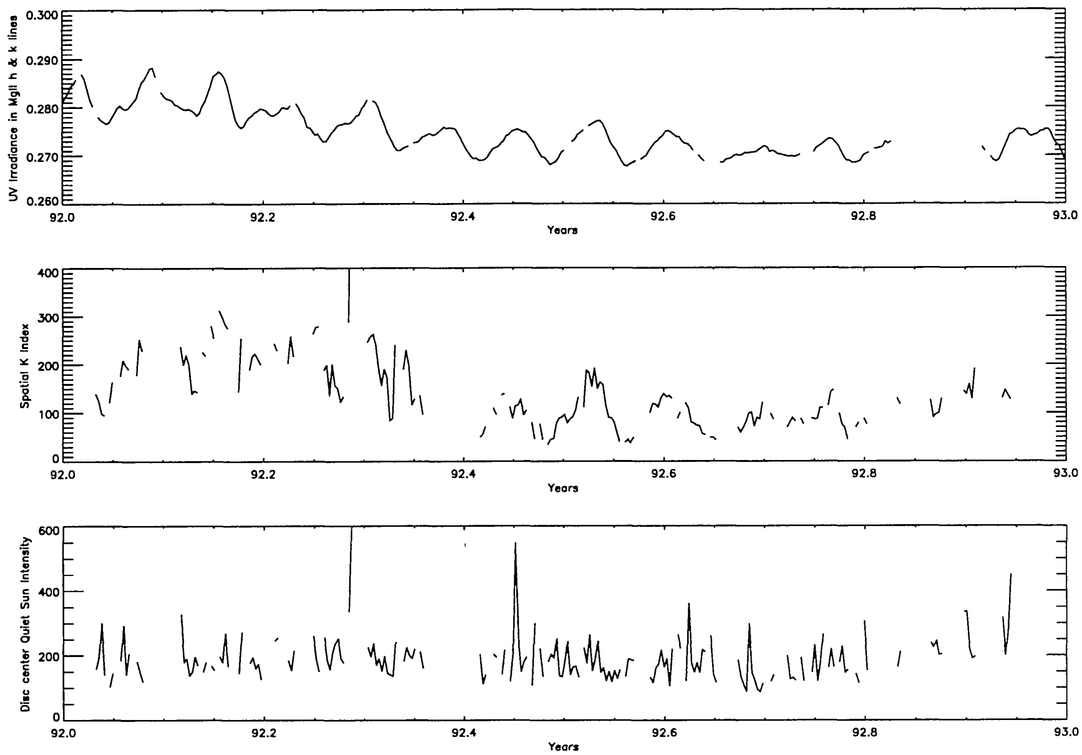

Figure 1. Time series of (from bottom) quiet-Sun intensity at the center of the solar disc, the spatial K index, and MgII c/w ratio measured with NOAA9/SBUV2 satellite for the period 1992.

K spectroheliograms of 1992 and 1980, after correcting for the photographic background emulsion. We have averaged the pixel intensity values of an area: 36 arcsec by 36 arcsec at the center of the disc in a very quiet-network and intranetwork regions from all the images. In Fig. 1 we present the time series of the quiet-Sun intensity, the spatial K index (the full-disk intensity, Paper I), and MgII c/w ratio of NOAA9/SBUV2 instrument for the year 1992. It can be seen from Fig. 1 that the quiet-Sun component will vary in general with the spatial K index and MgII c/w ratio, but may not show a peak-to-peak correlation in variation. The general solar cycle trend can be clearly seen in the quiet-Sun variability. In Fig. 2, similarly we have presented the time series of the quiet-Sun intensity, the spatial K index, and MgII c/w ratio of Nimbus7/SBUV1 instrument for the year 1980. The similar solar cycle trend in the quiet-Sun variability can also be seen for the year 1980. The longer-term variation of the quiet-Sun intensity during the solar activity cycle is nearly in phase with that of the spatial K index and UV irradiance in MgII h and k lines, suggesting that emission flux disappearance continues in the quiet-Sun regions, though it occurs at a slower rate than is observed in active regions. Harvey (1992, 1994) presented the total magnetic flux variation in active and quiet regions, and she suggested that the magnetic fields in the quiet-Sun are a important aspect of the total magnetic flux on the Sun, particularly during the minimum phases of the cycle when activity is minimal. In addition, she has listed the possible contributions

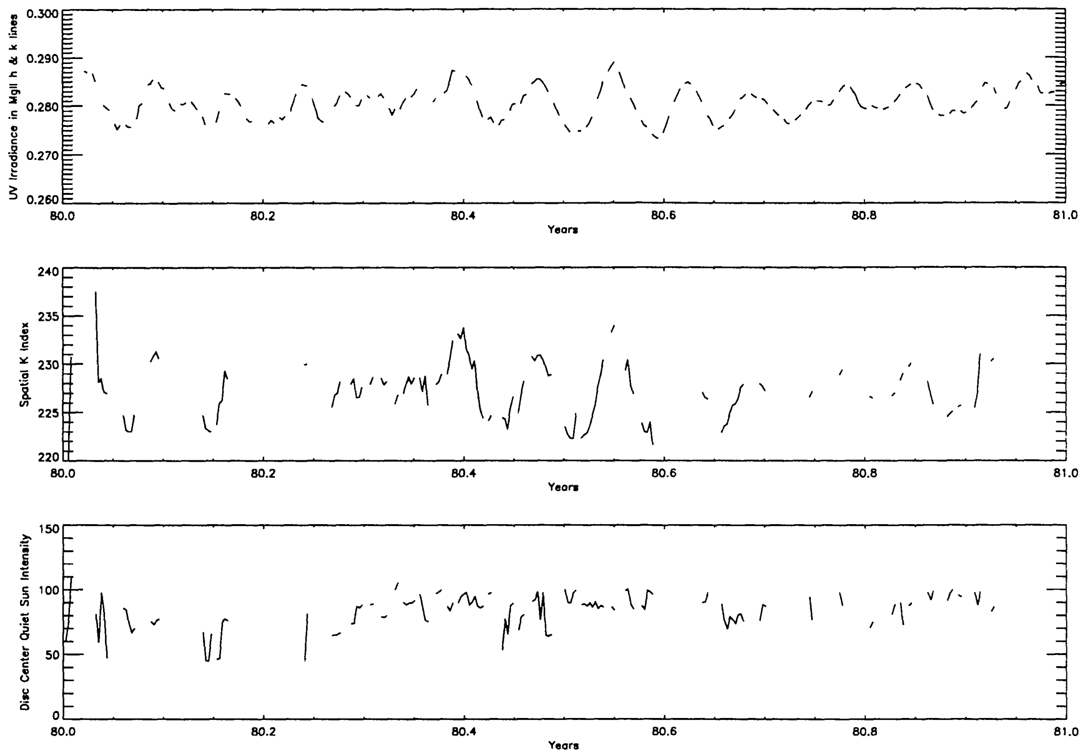

Figure 2. Time series of (from bottom) quiet-Sun intensity at the center of the solar disc, the spatial K index, and MgII c/w ratio measured with Nimbus7/SBUV1 satellite for the period 1980.

to the magnetic fields in the quiet-Sun are: (i) the dispersing active region fields from previous old cycle or cycles and the incoming new solar cycle; (ii) ephemeral regions; and (iii) an ever present background field. There are evidences for the contribution of intranetwork regions to K-emission flux and UV irradiance variability (Kariyappa, Sivaraman, & Anandaram 1994; Kariyappa 1994, 1996, 1998; Paper I), and Martin (1988) suggested that the intranetwork fields will be continuously produced and contributing to total magnetic flux. Thus, the emission flux in the quiet-Sun varies in phase with the solar activity but by a smaller factor than that in spatial K index, and UV irradiance. We suggest that the quiet-Sun will contribute quite significantly to the total K-emission flux and UV irradiance variability observed in MgII h and k lines, and show a solar cycle variation.

The study of periodicities in solar observational data has long been a high interest. The existence of a long-term cycle about 11-year, and short-term 27-day periods have been well established in numerous solar indices and in active regions. A search for periodicities in quiet regions would have fundamental significance for our understanding of solar magnetic activity, and the dynamics of the chromosphere. We have done a power spectrum analysis on the time series of quiet-Sun data of 1992 and 1980 separately. The power spectrum plots (not presented here) show a strong peak around 51-day period. This evidence suggests that the 51-day period may be related to a new emerging weak magnetic fields, and the emission flux disappearance continues in the quiet-Sun regions at a slower rate. The 51-day period is also found in other indices: total irradiance, and projected areas of active regions (Frohlich & Pap 1989, Pap, Tobiska, & Bouwer 1990), and in the occurrence rate of major flares (Bai 1994).

4. Conclusions

We have used the digitized CaII K spectroheliograms (Paper I) observed at the National Solar Observatory / Sacramento Peak for the period 1992 and 1980 to extract the quiet-Sun component at the center of the solar disc in a very quiet-network and intranetwork regions, and compared with the spatial K index (the full-disk intensity) and the UV irradiance measured in MgII h and k lines. It is shown, *for the first time in K-line*, that the quiet-Sun component will vary in correspondence with the solar magnetic activity. The longer-term variation of the quiet-Sun is in phase with the full-disk K-emission flux (the spatial K index), and UV irradiance. These results suggest that the variations in quiet-Sun will contribute in the variations of UV irradiance and its contribution should be taken into account in UV irradiance models.

The results of a standard FFT time series analysis show, *for the first time*, the 51-day periodicity in the quiet-Sun variability. The existence of the 51-day periodicity in the quiet-Sun variability suggests that it may be related to a new emerging weak magnetic fields, and the emission flux disappearance continues in the quiet-Sun regions at a slower rate. The variability of the chromospheric quiet-Sun suggest that it is very dynamic, *not quiet*, and is crucial for understanding and clarifying of the chromosphere itself.

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