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# Network and plage indices from Kodaikanal Ca-K data

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**Abstract**  The Ca II K filtergrams from Kodaikanal Solar Observatory have been used to study solar activity. The images are dominated by the chromospheric network and plages. Programs have been developed to obtain the network and plage indices from the daily images as functions of solar latitude and time. Preliminary results from the analysis are reported here. The network and plage indices were found to follow the sunspot cycle. A secondary peak is found during the period of declining activity in both the indices. A comparison of network indices from the northern and the southern hemispheres shows that the former is more active than the latter. However such an asymmetry is not clearly seen in the plage index.

**Key words:**  Sun: chromosphere

## 1 INTRODUCTION

The calcium II K images of the Sun from Kodaikanal Solar Observatory have data that span about 100 years and contain information on more than nine solar cycles. This provides a good opportunity to study solar activity in great detail. Only Mt. Wilson in the USA has a comparable span of data (Foukal et al. 2009). The Ca II K line at 3934 Å is a chromospheric emission line and the images are dominated by the chromospheric network and plages. The chromospheric network is the bright emission network which outlines supergranulation cells (Simon & Leighton 1964). Convective motions in the supergranules sweep magnetic field elements - small flux tubes - to their edges, resulting in field concentrations which produce enhanced emission at the cell boundaries. The plage is the bright chromospheric region, part of the active region outside sunspots.

Supergranular convection plays an important role in maintaining the solar cycle. When active regions on the solar surface disintegrate, magnetic flux disperses along supergranular boundaries through a random walk process and neutralizes the polar fields. As the Ca K chromospheric network is a manifestation of supergranulation, the Ca line is a good tracer of magnetic activity. Although total solar irradiance variations are only of the order 0.1% over the solar cycle, the UV irradiance shows much larger variations (Johannesson et al. 1998). The UV radiation in the upper atmosphere is believed to play a role in Earth's climate. The Ca K line is a proxy for the UV irradiance and hence it is particularly useful in the pre-satellite era.

In this preliminary study, we have used about 100 Ca K filtergrams, one from every month, during 1997–2007, from Kodaikanal to obtain the activity indices. The indices represent the fractional area of the feature over the solar disk. We have developed codes for calculating network and plage indices. The data analysis and some preliminary results are explained in the following sections.

## 2  OBSERVATIONS

Routine Ca K observations have been conducted in Kodaikanal since 1906 (Bappu 1967). The spectroheliograms which were recorded in photographic plates are presently being digitized and calibrated. In 1995, the observational setup was changed to get filtergrams using a narrow-band (pass band = 0.12 nm) Ca K filter and a CCD camera with a format of 1K×1K, but with the same old siderostat. These filtergrams are used in the present work. It may be noted that there are gaps in the data due to bad weather and problems with the instrument. The long gaps in the data are mainly seen in the rainy season. A typical example of a filtergram is shown in Figure 1. The pixel resolution is about 2.5 arcsec. This arrangement was replaced by a twin telescope in 2008 (Singh et al. 2012).
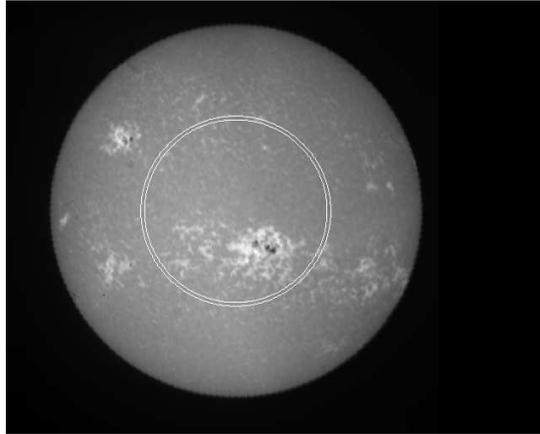


**Fig. 1** The Ca K image from Kodaikanal observatory. One of the 50 concentric rings with equal area used in finding the background intensity is also shown.

## 3  DATA ANALYSIS

The Ca K filtergram was usually taken in the middle of the month. When this was not available, one from a nearby day was taken. The data analysis involved the following steps.

(1) Correction for image rotation: since a siderostat was used in the observations, the images rotate with time. Hence the filtergrams need to be corrected for the rotation.
(2) Center and radius of the solar image: the (X,Y) positions of the limb were noted and then fitted with a circle which gives the center and radius of the image.
(3) Background intensity: the quiet-Sun background intensity was determined according to a technique described by Brandt & Steinegger (1998). The solar disk is divided into 50 concentric rings of equal area (Fig. 1). In each of the rings, the 5% value in the cumulative intensity histogram was found and all intensity values in the ring were replaced by this value. The quiet-Sun background intensity thus determined was used to normalize the individual images. This also corrected for the limb darkening.
(4) Polynomial fit: each 10 degree latitude strip of the normalized image was fitted with a second degree polynomial surface. The strip was then divided by the polynomial fit which smoothened the sharp gradients.
(5) Identifying network and plage points: the intensity thresholds for network and plage were decided by trial and error. They were found to be 3% and 10%, respectively.

## 4 RESULTS AND DISCUSSION

The network and plage indices were obtained from the images. The variation of network index during the period 1997–2007 is given in Figure 2. The monthly sunspot number is also plotted alongside. It may be seen that the network index generally follows the sunspot cycle. A secondary peak can also be seen during the period of declining activity. The network index shows a variation of about 8% between the solar maximum and minimum.

In Figure 2, variation of the plage index is plotted for the same period. The behavior of the plage index is similar to that of the network index. The plage index follows the solar cycle more clearly than the network index and also shows evidence of the secondary peak. The variation between the solar maximum and minimum is about 5%.

The value of the network index found by us (0.05–0.13) is much less than the value usually reported, which is up to 0.3 (Worden et al. 1998; Singh et al. 2012). This is because of the higher thresholds chosen by us in order to avoid network points that are doubtful. Hence our values can be taken as enhanced network indices. The reason for the secondary peaks is not clear but could be due to the emergence of excess active regions in the declining period.

The differences of the indices in the northern and southern hemispheres were also obtained. These are plotted in Figure 3. It can be seen that, in the case of the network index, the northern hemisphere is more active than the southern hemisphere. However, the plage index does not show such a clear difference between the northern and southern hemispheres.

The north-south asymmetry in the activity of solar cycle 23 has been reported (Joshi & Joshi 2004; Li et al. 2009; Bankoti et al. 2010). An overall dominance in the southern hemisphere is observed. The northern hemisphere is more active during the ascending years of the cycle but there is a transition to a more active southern hemisphere during the later years. Our results, in general,
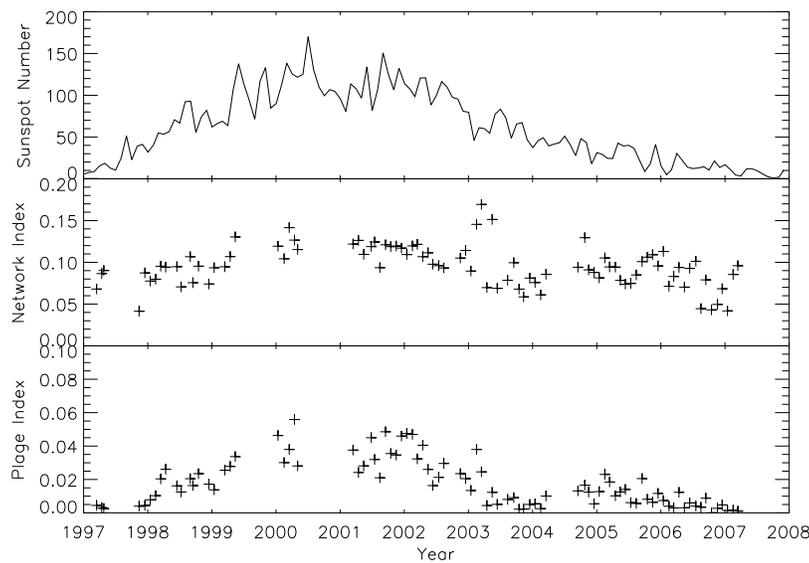


**Fig. 2** Variation of network and plage indices with time. The monthly sunspot number is plotted as a solid line in the top panel.
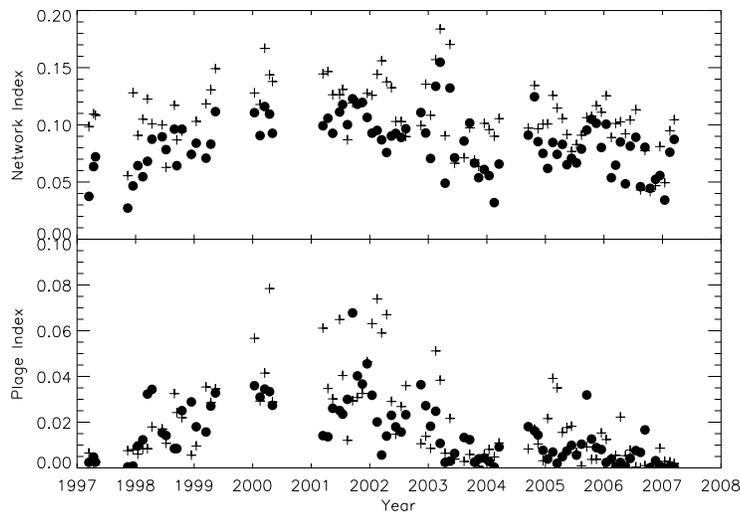
**Fig. 3** North-South differences in network and plage indices. A plus indicates points from the northern hemisphere and a filled circle indicates those from the southern hemisphere.

do not agree with the above findings, although there is some consensus regarding the activity during the ascending years. This aspect needs to be examined in more detail.

## 5 CONCLUSIONS

A preliminary study of solar activity using Ca K filtergrams from Kodaikanal during the period 1997–2007, which mostly covers solar cycle 23, has been carried out. The network and plage indices were obtained during that period and they were found to follow the sunspot cycle. A secondary peak during the declining activity was found in both network and plage indices. A comparison of network indices from the northern and southern hemispheres shows that the former is more active than the latter. However, such an asymmetry is not clearly seen in the case of the plage index.

As a future work, the activity indices will be obtained from the 100-year data. The behavior of the indices in the individual latitude bands will also be be studied.

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