Long-Term Datasets for the Understanding of Solar and Stellar Magnetic Cycles
Proceedings IAU Symposium No. 340, 2018
D. Banerjee, J. Jiang, K. Kusano & S. Solanki, eds.

doi:10.1017/S1743921318001473

Reconstruction of solar activity according to the data of centenary observations

Kseniya A. Tlatova[1], **Valeriya Vasil'eva**[1] **and Andrey Tlatov**[1,2]

[1]Kislovodsk mountain astronomical station of the Pulkovo observatory,
357700, Gagarina str. 100 Russia
email: `k.tlatova@mail.ru`

[2]Kalmyk State University, Elista, Russia

Abstract. Digitization of solar activity data over a period of more than 100 years has been performed. The database presents the characteristics of sunspots, sunspot umbras, filaments, plages in CaIIK line and prominences. The series of vector boundaries and photometric properties of the selected objects are created.

The characteristics of individual types of solar activity were determined. An interactive atlas of solar activity has been created, on which daily maps of solar activity, characteristics of individual elements and summary indices of solar activity are presented. The indices of solar activity were reconstructed and the analysis was carried out.

Keywords. Sun, solar activity, long-term variations

1. Introduction

We performed the digitization of long-term archives of observations of solar activity. The database includes the digitization of photographic archives of daily solar synoptic observations. Including: magnetic fields of sunspots on the sketches of Mount Wilson Observatory (MWO) of $1917 \div 2016$; sunspots on photographic plates of the Greenwich Observatory (RGO) of $1919 \div 1972$ and Kislovodsk $1954 \div 2017$; plages in the spectral line CaIIK in the period $1905 \div 2016$ according to the observatories Kodaikanal, MWO, Sacramento Peak (SP) and Kislovodsk; solar filaments observed in the H_α line, for the period $1915 \div 2016$ according to the observatories Kodaikanal, Meudon, Sacramento Peak (SP), Kanzelhoe and Kislovodsk; prominences, according to observations in the H_α and CaIIK lines for the period $1910 \div 2017$, according to the data of the Kodaikanal observatories, and Kislovodsk and sketches of the international observational network of spectrohelioscopes.

2. Digitization of the long-term white-light archive of the RGO Observatory

The RGO archive of solar photographic observations for the interval $1918 \div 1976$ contains about 26000 plates obtained during the period of time from 1918 to 1972. The archive was digitised by Mullard Space Science Laboratory, University College London and converted into a series of FITS-format images with the resolution that corresponds to the sun's image radius having approximately 1600 16-bit pixel.

Special numerical algorithms have been developed for processing these images at the Kislovodsk Mountain Solar Station of Pulkovo Observatory Tlatov *et al.* (2014). Our software includes also the manual screening tool for approving or rejecting the automatically localised sunspots. It is needed for removing photographic artefact and marks.

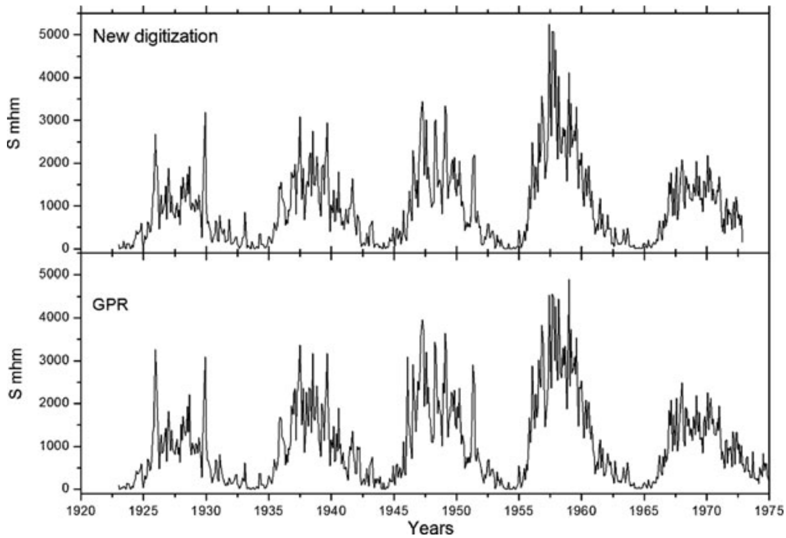

Figure 1. Comparison of the new measures sunspot areas and manual measurements Greenwich Photo-heliographic Results (GPR) in millionths of hemisphere (mhs).

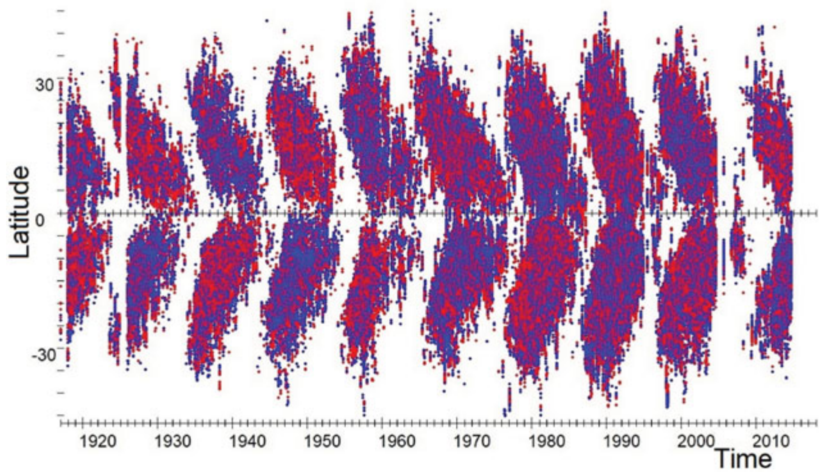

Figure 2. The latitude-time diagram of the measured umbras and pores with magnetic field polarity indicated in color (blue for positive and red for negative polarity).

The preliminary processing stage of each photographic plate includes the identification of the edge of the solar disc and the overlaying of the heliographic coordinate grid that would correspond to the observation date and time. The second part of image processing consists of building a sequence of calibrated images.

The calculated areas of these sunspots were compared with the results of manual measurements of the same regions (see Figure 1). The correlation between the automatic and manual results is quite high ($R \sim 0.97$). The regression equation can be written as $S_{GPR} = 46.7(\pm 15) + 1.05(\pm 0,01)S_{NEW}$.

https://doi.org/10.1017/S1743921318001473 Published online by Cambridge University Press

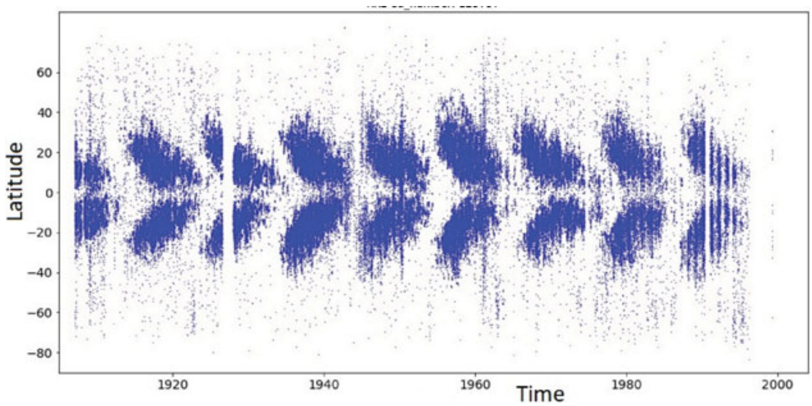

Figure 3. Butterfly diagram plages with ares $S > 1000$ mhm according Ca II K spectroheliograms from the Kodaikanal Solar Observatory.

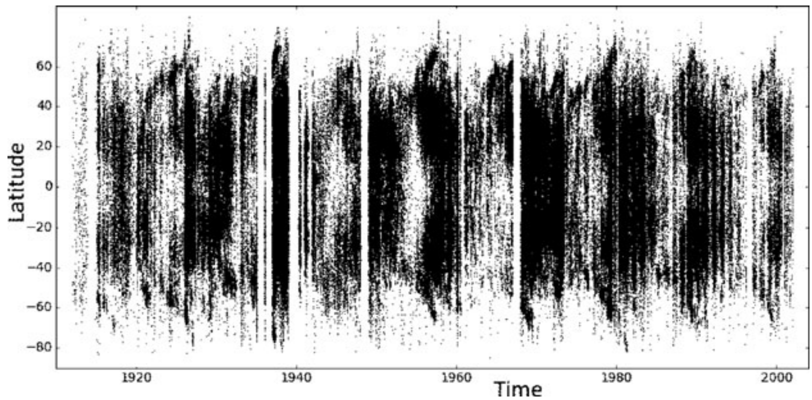

Figure 4. Latitude-time plot of the distribution of filament center locations for $1912 \div 2002$ in Kodaikanal observatory data.

3. Database of sunspot umbrae and pores observed at Mount Wilson Observatory (MWO) in $1917 \div 2016$.

The longest series of observations of sunspot magnetic fields exists at Mount Wilson Observatory (MWO) from 1917 until the present. The digitization of the MWO scanned drawings is done in the following steps. In the first step the code identifies and fits the solar limbs to the image. This establishes the transformation between the image and the heliographic coordinates. Next, the operator manually selects the location of individual umbras and pores to be digitized. The program automatically detects their outer boundaries following the procedure described in Tlatov *et al.* (2015). Then, the operator manually enters the intensity and polarity of the magnetic field of the respective structure. At each step, the operator verifies the validity of the automatic selection and can make adjustments to the automatic action when necessary.

Fig. 2 depicts the butterfly diagram (latitude-time plot) of the measured umbrae and pores. Each umbra and pore are marked at its position, and colored with its magnetic polarity, using blue for positive and red for negative polarity. Note that each wing of the butterfly is dominated by the color of the leading polarity umbras due to the larger number of leading polarity umbras (see later).

https://doi.org/10.1017/S1743921318001473 Published online by Cambridge University Press

4. Centenary activity of the Sun from observations in the CaIIK line

Arguably, Ca II K line observations are the most readily available data from ground-based observatories to characterize long-term solar activity in ultraviolet radiation. Furthermore, in the absence of direct measurements, the CaIIK index can serve as a good proxy for solar magnetic flux.

We analyze the synoptic data taken in the CaIIK spectral line with spectroheliographs at Kodaikanal Observatory from 1907 to 1999, at Mount Wilson Observatory from 1915 to 1985, and at the National Solar Observatory at Sacramento Peak from 1963 to 2002. Photographic data were digitized and calibrated following the same set of procedures developed by Tlatov *et al.* (2009). Using calibrated data, we have outlined bright plages and have calculated a plage index defined as the fraction of solar hemisphere occupied by the chromospheric plages and enhanced network. Figure 3 shows the latitude-time plot of plages center locations in the Kodaikanal observatory data.

5. Reconstruction of a hundred years series of solar filaments from daily observational data

The preliminary results of solar filaments distinguished in daily H_α observations at Kodaikanal ($1912 \div 2002$) are presented. To mark the boundaries of solar filaments, methods based on automated procedures of marking low-contrast objects on the solar disk, as well as editing of the marked boundaries in a semiautomated manner, were developed.

The new data set of solar filaments characteristics makes it possible to perform a thorough analysis of solar activity at different latitudes of the solar atmosphere. Figure 4 shows the latitude-time plot of filaments center locations in the Kodaikanal observatory data. Annual variation in the filament number, which is apparently associated with weather conditions and quality of the original photographic plates, may also be noted. The plot also features an equatorward shift, which is associated with the distribution of sunspot activity, and a poleward drift associated with the changing of the poles of the large-scale magnetic field during the activity cycle.

6. Conclusion

Several research groups are presently working on a reconstruction of the long-term indexes of solar activity based on the processing of long-term archive data. Studying the long-term variation of the magnetic fields of sunspots can provide unique information about the nature of the solar dynamo and the solar cycle.

Currently, these activity data are partially loaded onto the interactive atlas of solar activity (www.observethesun.com).

This work was supported by of the RSF N 15-12-20001 and RFBR N 18-02-00098.

References

Tlatov, A. G., Pevtsov, A. A. & Singh, J. 2009 *Solar Phys.*, 255, 239.

Tlatov, A. G., Kuzanyan, K. M., & Vasil'yeva V. V. 2016, *Solar Phys.*, 291, 1115

Tlatov, A. G., Vasilieva, V, V., Makarova, V. V., & Otkidychev, P. A. *Solar Phys.*, 289, 1403

Tlatov, A. G., Tlatova, K. A.; Vasil'eva, V. V.; Pevtsov, A. A.& Mursula, K. *Advances in Space Research.*, 55, 835