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Reconstruction of the Filament Properties, Based on Centenarian Daily Observations of the Sun in H_α Line

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Abstract. Preliminary results of distinguishing solar filaments on daily observation data at the H_α spectral line of the Kodaikanal Solar Observatory (1912-2002) are presented.

To distinguish the boundaries of solar filaments, methods have been developed, based on automatic procedures for distinguishing low-contrast objects on the solar disk as well as on editing the boundaries of selected structures in semi-automatic mode. An analysis of solar filaments' characteristics has been performed. We are considered variation of the average tilt-angle and the radius of curvature of the filaments in 15-23 cycles of activity.

Keywords. Sun, solar filaments, long-term variations

1. Introduction

The appearance of filaments on the Solar disk is associated with the distribution of active region magnetic fields as well as with large-scale magnetic fields. Filaments are observed in almost every latitude of the solar atmosphere.

Systematic H_α observations began around 1915 at the Kodaikanal Observatory (India), when J. Evershed used a spectroheliograph with a large variance spectral grid. In 1919, Meudon Observatory (France) started its observations using a spectrogeliograph, and since 1959 the Kislovodsk Observatory (Russia) started using Lio filter.

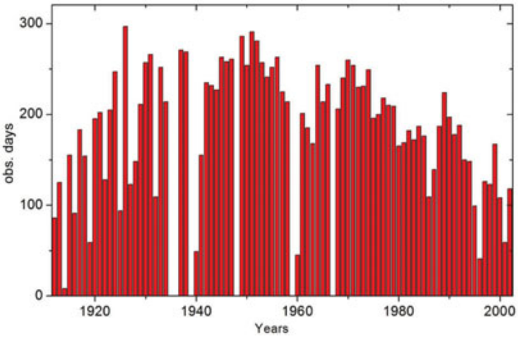
Long-term solar filament data can provide significant information about the properties of the solar periodicity. The solar filaments are located on the lines where the large-scale magnetic field changes. Thus, the analysis of filament data allows for the restoration of a large-scale magnetic field topology over a long period of time (McIntosh 1972, Makarov & Tlatov 2000, Mouradian & Soru-Escaut 1994, Tlatov 2009).

Previously, filaments at the synoptic maps for the period from 1919 to 2014 were digitized (Tlatov *et al.* 2016, Li 2010). This data included the digitization of intermediate lines of filaments, which were drawn manually on the synoptic maps of Meudon and Kislovodsk Observatories.

The purpose of this work was to create a series of filament features due to the daily observation data for the period of about 100 years, to create a data bank for the vector contours of filaments' boundaries, stored in the daily images of various observatories, and to provide a preliminary analysis of the data received.

2. Source data and processing method

This work focuses mainly on presenting the results of processing the daily data of Kodaikanal Observatory (India) for the period from 1912 to 2002. We used images of



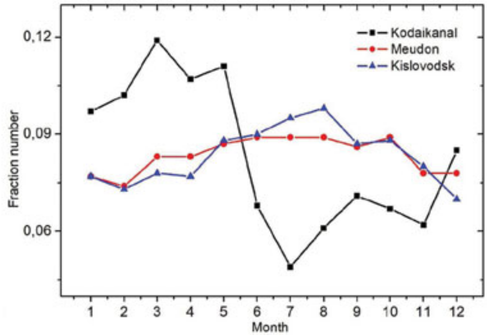


Figure 1. (On the left) The number of processed photographic plates of the Kodaikanal Observatory per year.

Figure 2. (On the right) A change in the number of filaments in observations of the Kodaikanal, Meudon and Kislovodsk Observatories depending on the month of a year.

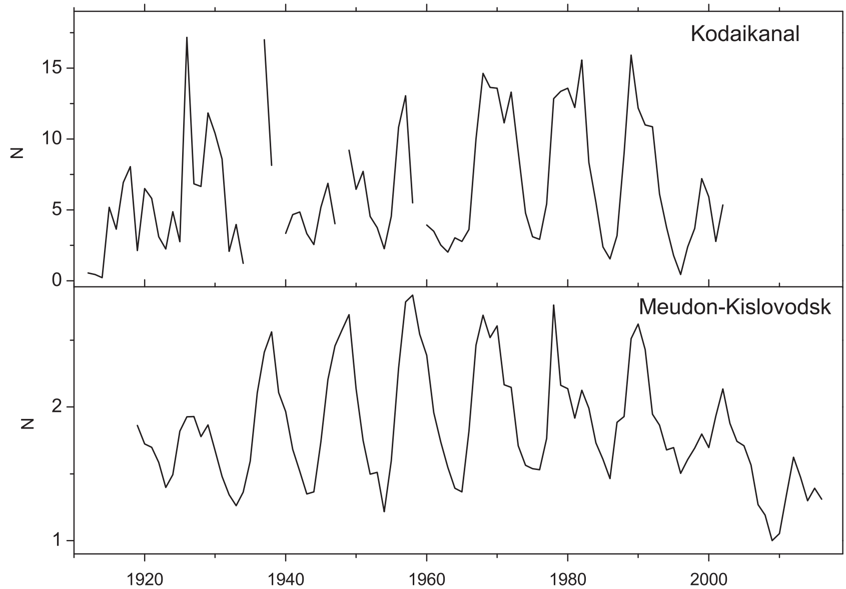


Figure 3. The average number of filaments per day, shown on the daily plates of the Kodaikanal observatory and synoptic maps of Meudon and Kislovodsk observatories.

800x800 pixels available on the web-site (http://kso.iiap.res.in:8080/KodaiArchiveData/) as a source data of Kodaikanal Observatory, as well as, in part, the digitized photographic plates, performed by A.G. Tlatov in 2000 at Kodaikanal Observatory.

Special software was developed to distinguish solar filaments. The algorithm includes several steps: distinguishing the solar limb and grid overlapping, dimness adjustment to the edge, finding the P-angle marker, distinguishing filaments above the level of the quiet Sun, and editing the selected objects by the operator. Our software provides both a fully automatic selection mode and a manual and semi-automatic editing mode, which distinguishes this software from other methods (Fuller *et al.* 2005, Hao *et al.* 2015, Li 2010).

In total we have allocated over 326 thousand filaments on 24308 images of Kodaikanal Observatory for the period from 1912 to 2002. Figure 1 shows the number of observation

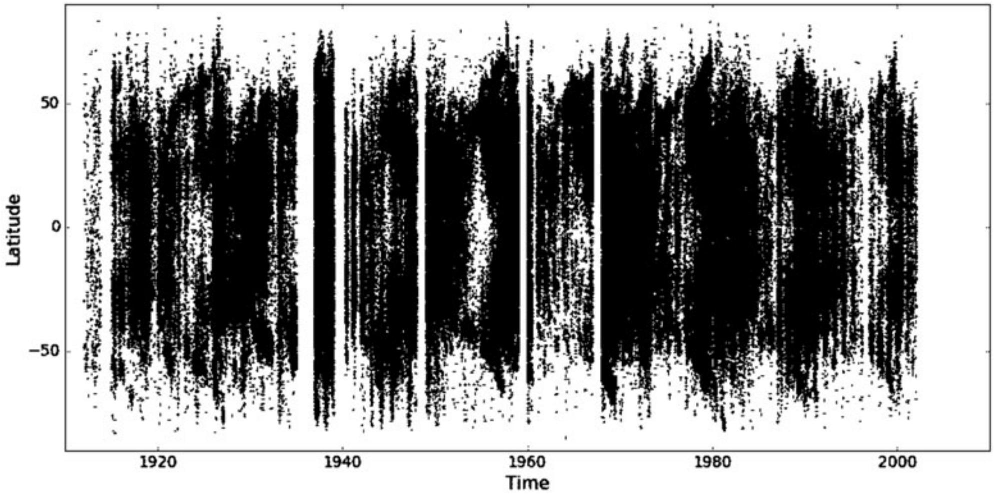


Figure 4. A latitude-time diagram of the position of filament centers.

days for the year that we have processed. We skipped a number of days, for example, in 1935-1936 and in 1959 due to lack of data on the web-site. We were processing all the photographic plates and sometimes even more than one per day. The number of filaments for recordings of no more than one plate per day made over 209 thousand pieces. The database includes both vector data of the filament shapes and text bases of measurements regarding filament parameters.

The processing of daily data from different Observatories is an important requirement for the creation of a unified filament database. Figure 2 shows a change in the relative number of filaments for Kodaikanal, Meudon and Kislovodsk Observatories. Data for Meudon Observatory was collected from the digitized synoptic maps (Tlatov *et al.* 2016). Data for Kislovodsk Observatory are presented at the website of the Observatory: http://solarstation.ru. We would like to mention that maximum observations in Kodaikanal Observatory were made during the first half of a year, while Kislovodsk and Meudon Observatories focused on the second half of a year.

The daily observation data provide much more information than the data presented on the synoptic maps. Figure 3 shows the average number of filaments per day received after processing daily plates of Kodaikanal Observatory and the number of filaments per day received from synoptic maps from Meudon Observatory (1919-2002) and Kislovodsk Observatory (2003-2014). The average number of filaments per day received from the daily plates of Kodaikanal Observatory made ~ 7, and from the synoptic maps ~ 1.8.

The new database regarding to the features of solar filaments provides a comprehensive analysis of solar activity at various latitudes of the solar atmosphere. Figure 4 provides a latitude-time diagram of the position of filament centers according to the data of Kodaikanal Observatory. Data for a number of years are not available, and this is due to an incomplete catalog available on the Internet. It is also possible to note the annual variation in the number of filaments, apparently related to weather conditions and the quality of the original photographic plates. The diagram shows filament drifting towards the equator, associated with distribution of the solar sunspots activity, and drifting to the poles associated with the process of pole-ward transport of magnetic flux in a cycle of activity.

Data of digitization of Kodaikanal filaments, supplemented with data of other Observatories, allows studying the topological properties of filaments for about 100 years.

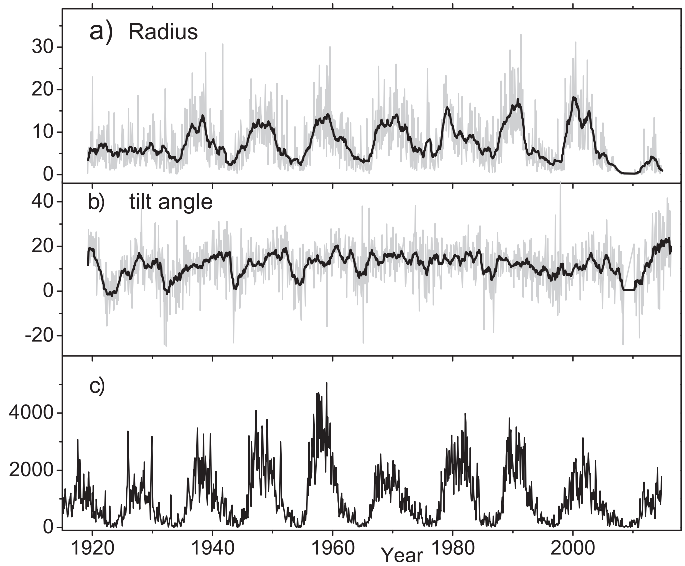


Figure 5. The variation in time a) the radius of curvature of the filaments in heliographic degrees; b) tilt-angle solar filaments c) the sunspots area for comparison.

Figure 5 shows the variation in time of the radius of curvature of the filaments in heliographic degrees, tilt-angle of solar filaments and the sunspots area for comparison.

3. Conclusion

A number of research groups are currently working on the reconstruction of long-term solar activity indices through the processing of long-term observational archives. The H_α observations are an important part of this work. Preliminary results of the processing of observation data from Kodaikanal Observatory for the years between 1912 and 2002 are presented in this paper. The daily data made it possible to distinguish filaments and analyse the activity in the H_α chromospheric line for over a long period of time. The resulting line showed greater stability than other available data lines. The data obtained have a great potential for analysing the properties of solar filaments and a large-scale magnetic field.

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