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Recent advances in the Debrecen sunspot catalogues

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Abstract. The Debrecen Photoheliographic Data (DPD) sunspot catalogue contains the mean positions and total areas of sunspot groups, and the position and area data of each spot derived from daily ground-based white light observations. The CCD scans of sunspot groups make the morphological studies available. Recently the SOHO/MDI-Debrecen Data (SDD) hourly sunspot catalogue has been started compiling by using the SOHO/MDI continuum (Ic) images and the suitably modified software developed for DPD. We describe the main characteristics of these catalogues, and their advantages. We summarize the recent advances in procedure of their compilation, and the available sets of the data and images.

Key words. Sun: sunspot data and images

1. Introduction

Position and area data of sunspot groups for every day were published at Greenwich (Greenwich Photoheliographic Results) until 1976. After that date Debrecen Heliophysical Observatory took over this responsibility.

The Debrecen Photoheliographic Data (DPD) (Győri et al. 2004) is mainly compiled by using white light full disk observations taken at Debrecen Observatory (with the most sunny hours in Hungary) and its Gyula Observing Station (with a telescope at 43 m height above the surface). Observations of several other observatories help in making the catalogue complete: Abastumani, Ebro, Helwan, Kanzelhöhe, Kiev, Kislovodsk, Kodaikanal, Mount Wilson, Rome, Tashkent, Tokyo, Valasske Mezirici, and SOHO/MDI.

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2. Debrecen Photoheliographic Data

The DPD completely covers the whole year with 1 observation/day time resolution. It gives account of all sunspots, even the smallest ones, both umbrae and penumbrae. The numerical part contains area and position of each spot, the total areas and the mean positions of the sunspot groups, and the daily sums of the area of groups. The following data are available for each spot: time of observation, the NOAA number of its group, the measured (projected) and the corrected (for foreshortening) areas of umbrae and the whole spot, latitude (B), longitude (L), distance in longitude from the central meridian (LCM), position angle and distance from the disk's center expressed in solar radii. Precision of position data is ~ 0.1 heliographic degrees, and that of area data is ~ 10%.

Images appended make the detailed morphology available. Scans of sunspot groups are

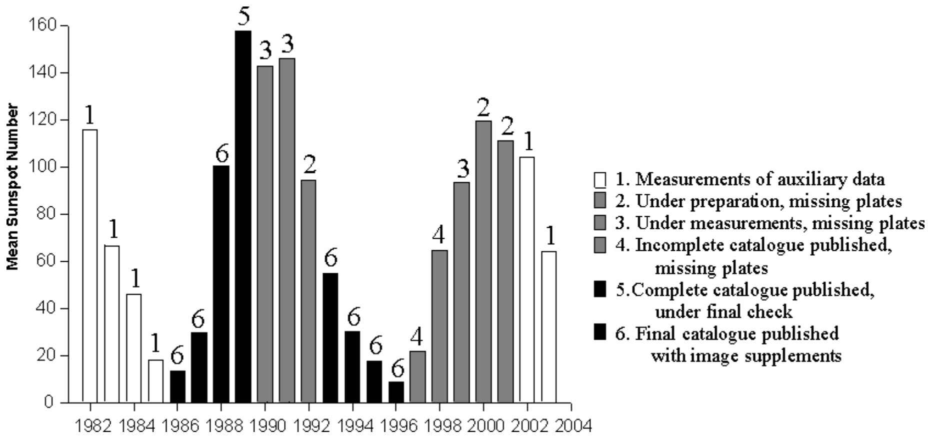

Fig. 1. Present status of DPD. Level 1: gathering the plates to be measured; creating files of observational and telescopic data. Level 2: identifying of groups on the plates; preparation to their measurements. Level 3: making CCD scans; position and area measurements. Level 4: publication of preliminary data, searching for missing plates to cover the year. Level 5: final check of the data; creating FITS and JPG images. Level 6: publication of the final data and images.

available in JPG and FITS format with numbered spots. Now the extension of the image set is in progress: scans of full disk white light observations will be provided for the forthcoming and previous catalogues as soon as possible. Figure 1 shows the present status of DPD.

3. Digitalizing and measuring photoheliograms

The instrumental background for DPD catalogue compilation has changed over the years. At the beginning the image of every sunspot group were separately taken by a CCD camera to achieve proper resolution. The CCD image was used to determine the area of the sunspots and their positions (relative to the CCD frame). An *xy* coordinate measuring instrument was used to determine the solar disk radius and the disk center from limb measurements. Moreover, large number of spots from each sunspot group were measured by this instrument to position the CCD images of the groups to the solar disk. Taking the CCD images of each sunspots separately and measuring the solar limb and position of the sunspots were equally time and man power consuming processes. The years 1986-89 and 1993-97 were processed by using these instruments.

In the year 2003 a professional scanner was bought. With this scanner we can perform full disk scans of our photoheliograms (solar disk diameter is about 10cm) with suitable spatial resolution (image size is about 8000x8000 pixels) and intensity resolutions (16 bit) as well as large enough density range (~ 4).

It worth saying a few words about why this image size (8000x8000 pixels) was chosen to use when compiling DPD catalogue. To determine the resolution used when scanning solar images one can make use of Rayleigh limit of the heliograph. For example this limit in our case (in Gyula and Debrecen) is 1.4 arcsec (pupil=10 cm, wavelength=554 nm). The image size (in pixels) corresponding to this limit is about 1400x1400. Taking into account Shannon's sampling theorem we must double this so we get the 2800x2800 image size. If we compare the original photoheliogram with the scanned image of that size the result is not satisfactory. Details that can well be observed on the originals disappeared in the scanned images. Two causes for explaining this discrepancy can be taken into consideration. The first, the Rayleigh limit is quite arbitrary (Kitchin 1984). For sources of nearly equal brightness (solar granulation, small spots in the photosphere, penumbral structure) finner resolution than the Rayleigh limit can be achieved. The second, it is also conceivable that there is some interaction between the neighboring pixels of the digitizing instrument and this decreases its resolution. Several tests were made with various resolutions. Using the 10000x10000 image size (2400 dpi in our films) no difference between the original and the scanned images were observed. Under image size 7000x7000 well defined differences were observed. From these tests the following thumb rule can be derived: choose the resolution of the scanner such a way that the image size should be between 7000x7000 and 10000x1000 (i.e., 5-7 times finner than derived from the Rayleigh limit).

The software package called SAM (Sunspot Automatic Measurement) (Győri 1998, 2003, 2005) was developed to handle and automate (as far as it is possible) the compilation of the sunspot catalogue.

The photoheliograms often contain various type of artifacts (i.e. emulsion defects, developing unevenness, scratches, fluffs, labels and different signs), and their quality are also very different depending on such factors as seeing, weather, exposure, developing and gamma of the film. In addition, if we want to issue a catalogue without gaps we must process extremely bad photoheliograms too, especially in autumn and winter times. Although SAM is continuously developed to cope with these problems the automatically created catalogue is subjected to extensive automatic and manual checking so that the DPD will be as accurate as it can be under the given circumstances.

4. SOHO/MDI-Debrecen Data

The software package SAM developed for DPD works not only on the ground-based photographic observations. It can be also applied to any full disk digitalized solar image if the orientation of the image is known or can be derived from the image itself. This feature of SAM enables the extension of the DPD project to the SOHO/MDI imagery.

The MDI Ic images (1024x1024 pixel) are obtained (and used as proxies for the continuum intensity near the Ni-I absorption line at 676.8 nm) by combining the standard five filtergrams (Scherrer at al. 1995). We use the Full Disk Continuum images from the Hourly Data Sets Level 1.8. In this data set there are observations with different time resolution (from one/day to one/min) in different time intervals. In the latest years usually there is one Ic image per hour but not in every hours. To get a data set with a more or less regular time resolution that contains the most available images we have decided to use one image/hour time resolution. The best available Ic image is chosen within the time interval (hour - 30 min, hour + 30 min) which is the closest to the center of the time interval. If an hourly data is missing, it means that there was no observation in the given time interval, or the available observation was not measurable.

The new database is called SOHO/MDI-Debrecen Sunspot Data (SDD) catalogue. This catalogue is similar to that of DPD in its data format and image products but the time cadence is 1 hour when MDI observations allow it. The numbering of the sunspot groups is based on the NOAA numbering used in DPD but some further suffices (s, t, etc.) have to be applied for those groups which are only observed by MDI. The numerical part also contains some slight differences. In the SDD there are "h" rows for the hourly data instead of the "d" (day) rows of DPD. The format of "h" row is also slightly changed because of the demand for higher accuracy of time data. In general, the users should check the formats of the rows from time to time because they will be changed if it is needed (e.g. the planned extension of SDD with magnetic and contrast data can be realized). The set of images contains the FITS and JPG images of sunspot groups like in the DPD, but it also contains the selected Ic images in the original form and in the processed form as well as the magnetograms observed by MDI. The full disk SOHO/MDI Ic images are enlarged (3x), corrected for limb darkening, flat fielded and transformed to negative. The best available magnetograms closest in time to the Ic images are chosen from the merged data sets of Full Disk Magnetograms of the Hourly Data Sets and Daily Data Sets. The SDD is available for 1996 at present.

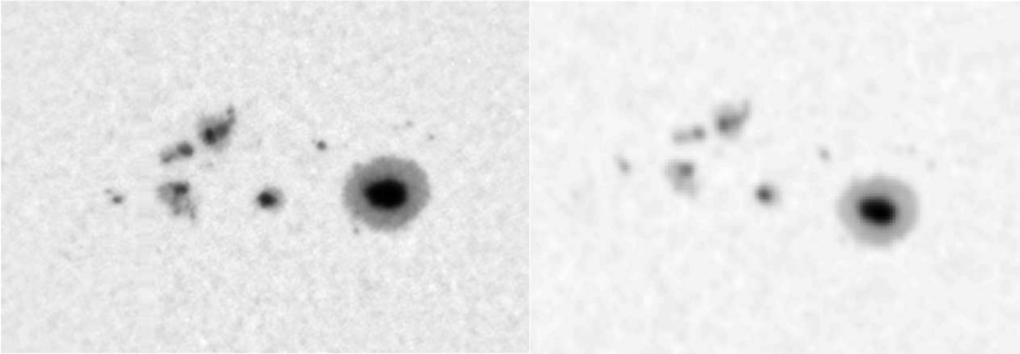

Fig. 2. Two images of active region NOAA 7981 on 1996 Aug. 2 taken within 17 minutes: DPD photoheliogram observed in Debrecen at 14:31 UT and MDI continuum image observed at 14:48 UT.

5. Summary

By using the sunspot data various investigations can be carried out in the following fields:
- Interactions of magnetic and velocity fields: Rotation (diff.rot., tors.osc.); Meridional circulation; Giant convection cells; Active region tilts; Convection; Thermal motions
-Temporal behavior of the activity: Periods longer than 11 years; Time-profile of the cycle; Mid-periods, quasi-biennial fluctuation
-Distributions on the disk: East-West asymmetries; North-South asymmetries; Active longitudes, nests; Polar activity belts; Statistics on spot sizes; Fragmentation of sunspot groups (leading-following asymmetry)
-Irradiance: Sunspot blocking models
-Solar-Terrestrial Physics

The advantages of the DPD predominate on temporal scales from a decade to a day and on spatial scales from the full disk to about 1 arcsec. The main advantage of SDD is the roughly hourly time resolution.

The electronic versions of the DPD and SDD are freely downloadable, and easy to use for search and selections. The data and images are available on the site of Debrecen Observatory at http://fenyi.solarobs.unideb.hu/.

The ftp site is mirrored at NOAA at http://www.ngdc.noaa.gov/stp/SOLAR/ftpsunspotregions.html.

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