PUBLICATIONS OF DEBRECEN HELIOPHYSICAL OBSERVATORY
Heliographic Series No.1
Appendix 2

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MEASUREMENTS OF SUNSPOT AREAS USING VIDEO FACILITIES IN DEBRECEN AND COMPARISONS TO SOME PUBLISHED GREENWICH DATA

1. THE DAREAL AND THE METHOD OF MEASUREMENT

The instrument is constructed to measure sunspot areas on photoheliograms by means of video techniques. The instrument, called by us in brief DAREAL, is outlined in Figure 1. A portion of the Sun's disc, with the spot to be measured, is projected through a magnifying lens system in a suitable enlargement to the photo-target of a TV-camera. The image of a portion of the Sun's disc can be examined on the screen of a TV-monitor, where the diameter of the solar disc is between 2 to 4 m in general. During the measurement of an umbra (or a whole spot) the brightness and contrast of the solar TV-image should be adjusted in such a way that the boundary of the umbra (or the spot) should look as it would by visual inspection of the original negative. The DAREAL enables us to select different portions of a sunspot group for measurement using a quadratic line, variable in size and position, as seen in Figure 2.

Over the image on the screen of the monitor it is possible to form any isodensity line of interest. The first phase and at the same time the essentials of the measurement is to find that isodensity contour which best fit to the boundary of the umbra (or the whole spot) area to be measured. Blinking contours makes it easier to fill this requirement.

In the second phase of the measurement, the actual determination of the area, within the contour picked out, takes place by means of an electronic counter. In approximately less than a half second the mean of ten automatic measurements appears on the digital display in arbitrary units. The principle of the measurements is shown in Figure 2. The measurement itself corresponds to the counting of the units of a quadratic network line by line.

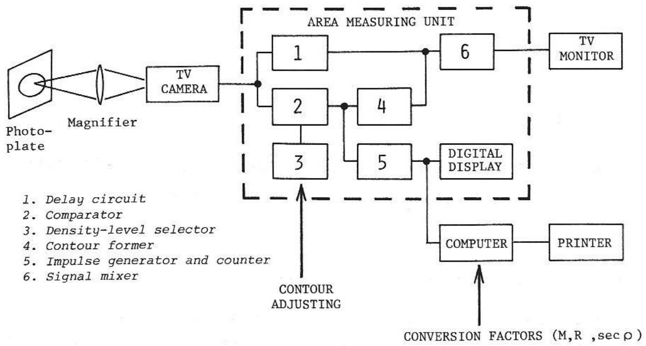

Fig.1 Schematic diagram of the Debrecen Area Measuring Instrument (DAREAL) (For the conversion factors M, R and sec ρ see the text.)

To get the areas in mm² an etalon, a predetermined area of a photographic (negative) image of a circle in mm², is also measured. The ratio of area of the etalon expressed in mm² and in the arbitrary units of the DAREAL is the *M* conversion factor. Knowing this *M*, as well as the radius of the Sun's disc in the heliogram (*R*) and the angular distance of the measured spot from the middle of the visible solar hemisphere as viewed from the centre of the Sun (ρ) the areas are recorded by means of a computer, expressed in millionths of the apparent Sun's disc and in millionths of the visible solar hemisphere.

Acknowledgements are due to Prof.G.Csikai who has given the possibility to make and to Drs. L.Vasvári, T.Sztaricskai and T.Schalbert who have carrying into effect the DAREAL at the University Institute of Experimental Physics in Debrecen.

2. THE SPOTS USED FOR CHECKING THE MEASUREMENTS

In order to test the DAREAL and at the same time to make a comparison between the Greenwich and Debrecen area measurements, two (*I* and *II*) independent sets of separated single spots were used.

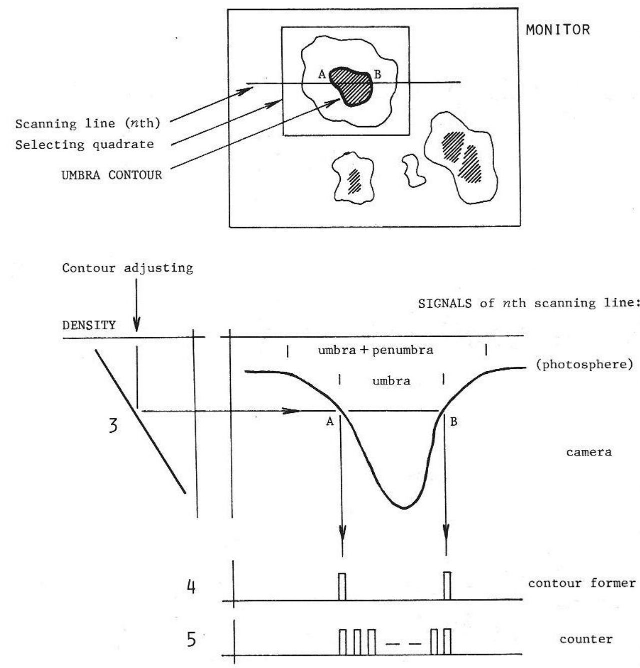

Fig.2 The working process of the DAREAL. (For explanation, see the text,cf.also Fig.1.)

I. Out of the material of observations obtained in Debrecen in the summers of 1966-1969 and 1971, the areas of almost 100 single spots of variable size were measured. More than half of the measurements relate to such instances when one spot itself comprised the whole group, while in other cases the measured spot was the largest spot of the group; however, their area data are also separately given in the *Greenwich Photoheliographic Results (GPHR)*. These spots belonged to 16 sunspot groups within 76° central meridian distance.

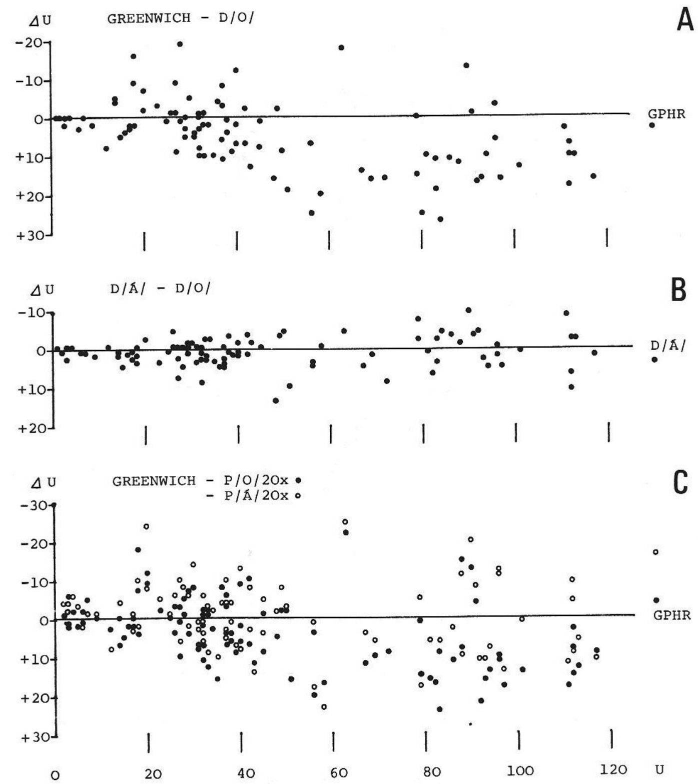

Fig.3.*I* Various sets of differences in umbra area measurements (ΔU) *versus* umbra area (U), in *sample I*.

A – Differences between published Greenwich data (GPHR) and DAREAL measurements (D) on Debrecen plates.

B – Differences between DAREAL measurements of two measurers /Á/ – /O/ on the same Debrecen plates.

C – Two sets of differences between published Greenwich data (GPHR) and PLANIMETER measurements (P) on (twenty times enlarged) projected drawings of Debrecen plates.

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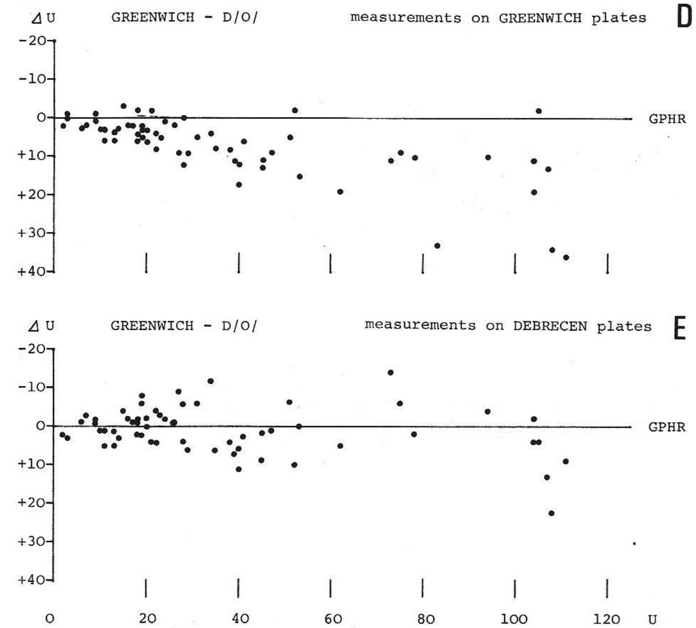

Fig.3.*II* Two sets of differences in umbra area measurements (ΔU) *versus* umbra area (U), in *sample II*.

D – Differences between published Greenwich data (GPHR) and DAREAL measurements (D) on Greenwich plates.

E – Differences between published Greenwich data (GPHR) and DAREAL measurements (D) on Debrecen plates.

For additional explanation, see caption of Fig.3.*I*.

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continued of caption of Fig.3.I.

/O/ and /Á/ indicate the initials of O.Gerlei and Á.Kovács who carried out the measurements.

The areas on the abscissa axis are recorded according to the published Greenwich data.

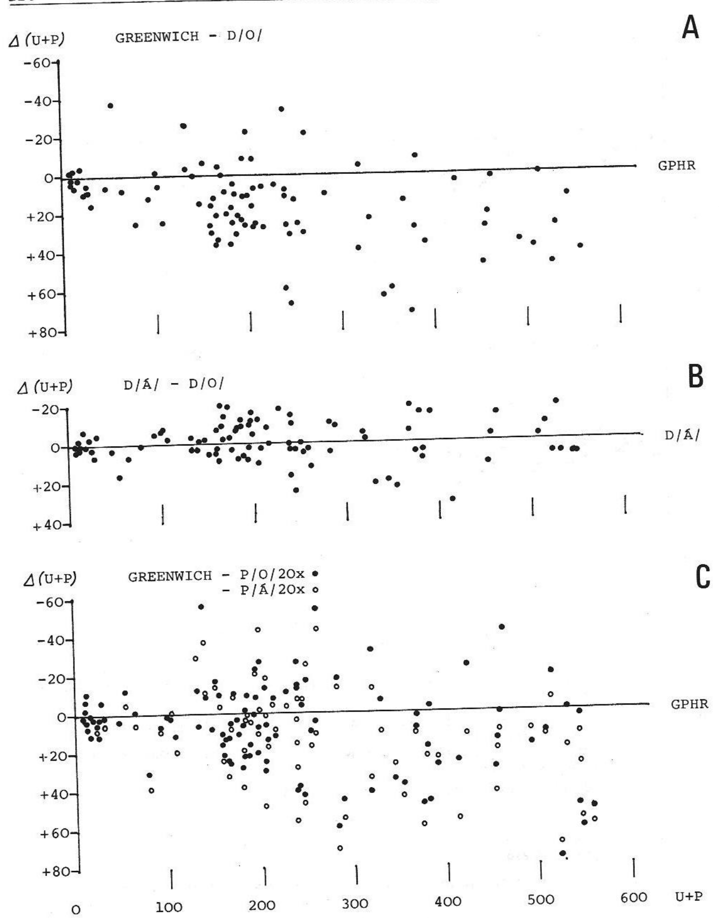

Fig.4.*I* Various sets of differences in umbra+penumbra (i.e.whole spot) area measurements [Δ(U+P)] *versus* umbra+penumbra area [(U+P)], in *sample I*.
Further explanation see in caption of Fig.3.*I*.

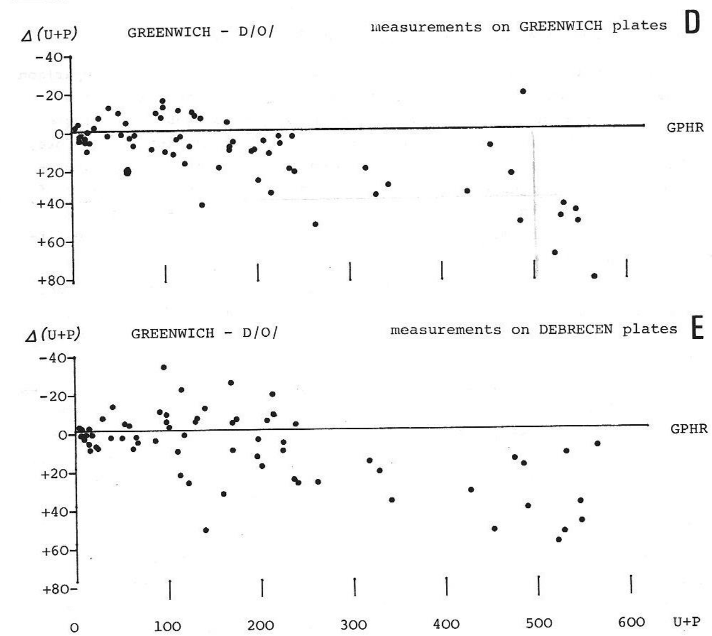

Fig.4.*II* Two sets of differences in umbra+penumbra (i.e. whole spot) area measurements [Δ(U+P)] *versus* umbra+penumbra area [(U+P)], in *sample II*.
Further explanation see in caption of Fig.3.*II*.

II. The second set consisted in two thirds of those 96 single spots which were also used in Kovács's paper relating to the data on positions (pp. 211-215). For these area measurements only such spots were utilized that have had a defect-free image on both the original Greenwich and Debrecen heliograms.

The diameter of the solar images in the Greenwich and Debrecen heliograms used here are 19 and 10 cm, respectively.

3. A COMPARISON BETWEEN GREENWICH AND DEBRECEN MEASUREMENTS

Unfortunately there were not enough spots available to make comparison between the Greenwich and Debrecen area measurements on the basis of an exact statistical analysis. For this purpose only those separated single spots are suitable which have Greenwich measurements published. Therefore, to be able to form a judgement on the comparison in question it is appropriate to show in Figures 3 and 4 in some detail the immediate results of our area measurements. All plots of the DAREAL measurements given in these Figures are the means of five successive measurements, i.e the fitting of contours took place five times.

According to parts A and E of Figures 3-4 there seems to be a slight deviation between the Greenwich and our area measurements. Both samples of spots (*I* and *II*) reveal more or less that the Debrecen area data are generally the smaller.

In trying to find a reasonable explanation, we first compared a series of measurements carried out independently by two persons, furthermore by applying a more conventional method. Part B of the Figures show that the DAREAL measurements of the two persons are in good agreement. On the other hand the repeated measurements on twenty times enlarged projected drawings by using a planimeter have also given roughly similar deviations as the DAREAL (cf. part C of Figures 3-4).

Finally, area measurements performed in Debrecen on original Greenwich plates and compared to the published Greenwich measurements, shown in part D of Figures 3-4, yield the same results as the foregoing. It is to be seen most conspicuously in Figure 5, where all data of the different kinds of Debrecen measurements (used in Figures 3-4) are plotted, that the areas measured in Debrecen are indeed slightly smaller. Some quantitative data of the deviations in question are given in Table 1, on the basis of the DAREAL measurements used in the A, D and E parts of Figures 3 and 4, when both kinds of spot areas were measured.

It is not surprising at all that the Greenwich and Debrecen area data do not agree perfectly. This obviously arises from the different method of measurements. In Greenwich "a glass diaphragm ruled into squares, with sides of one-hundredth of an inch (0.254 mm), and placed as nearly as possible in contact with the photographic film[was used]. The integral number of suqares and parts of a square contained in the area of a spot ... was estimated by the observer." {cf. *GPHR 1909*,p.X} Such a square corresponds to 2 millionths of the Sun's disc, whereas the unit of the DAREAL measuring network

is smaller by at least one order of magnitude, and therefore the boundary of the area can be followed more closely (as with a planimeter) and even parts of the millionth of the Sun's disc are directly counted. The discordances could arise only from the periphery of the area, i.e. it may be larger for the larger spots, since they have longer perimeters.

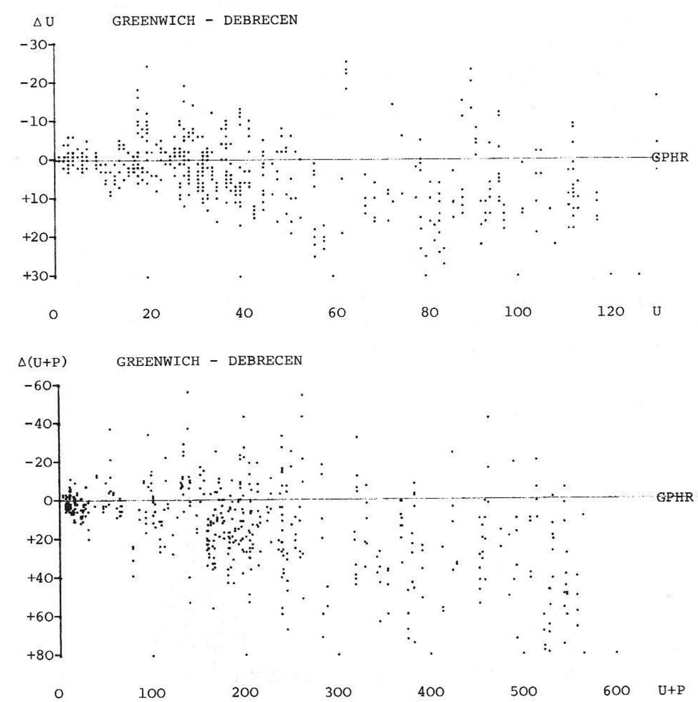

Fig.5 Differences between the results of Debrecen area measurements and published Greenwich area data *versus* the areas.
All data of Figures 3 and 4 are combined in the upper and lower part of the Figure, respectively.

Table 1

Deviations in area measurements between GREENWICH and DEBRECEN data

Size of AREA	UMBRA			UMBRA+PENUMBRA		
	0 - 20	21-50	50-120	1 - 100	101-250	251-600
MEAN DEVIATION	0	3	11	0	9	40
STANDARD DEVIATION	3	6	12	11	21	30
In the middle of the size interval	0%	9%	13%	0%	5%	10%
Number of spots available	68	86	65	49	104	66

The mean and standard deviation, as well as the areas are given in millionths of the solar hemisphere.

4. ON THE ACCURACY

It is well known that in smaller telescopes like our heliographs, the border of penumbra-photosphere is still well defined, while the umbra-penumbra border is generally much less distinct. Consequently, the error of measurement for the two kinds of spot areas are different. This is revealed by the examples of the two distributions given in Figure 6.

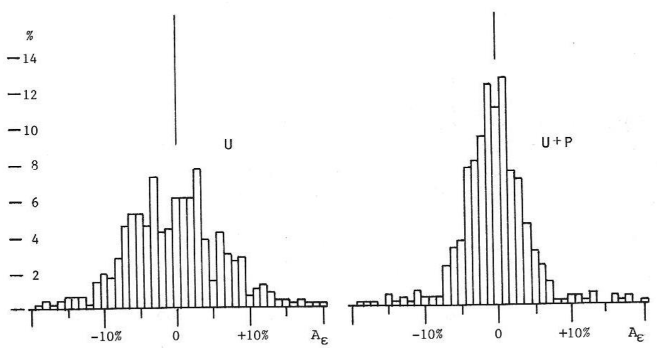

Fig.6 Frequency distribution of the scatter of deviations (A_ε) in U and U+P area measurements.

In Figure 6 all five individual measurements are used whose averages are plotted in part A of Figures 3.*I* and 4.*I*. Let A_i be one of the five single measurements and $\bar{A}$ their mean, then $100(\bar{A} - A_i)/\bar{A} = A_\varepsilon$ is the percentage deviation of A_i from $\bar{A}$.

In Figure 6 both the umbra and umbra+penumbra cases show a normal distribution. The standard deviations, 10% and 5%, for umbra and umbra+penumbra respectively, are in good approximation two to one (i.e. $\sigma_U = 2\,\sigma_{U+P}$).

These values can be regarded as the probable errors of the area measurements.

The errors principally come from the fitting of the measuring contour, which sometimes may be problematic close to the solar limb; however, some errors may also arise when the heliogram is not quite well exposed.Figure 7 shows an example of how the area of an umbra image can depend on the exposure. The error in determination of the etalon area may also have a slight influence on the area data, its maximum amount being 2%.

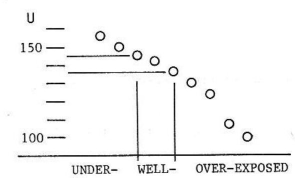

Fig.7 The effect of the exposure on the size of the umbra.

To get a more realistic idea of the accuracy of our area measurement of umbrae, the results of a two-day period of observation are shown in Figure 8 (on the next page).

The author thanks Ágnes Kovács for co-operation in these comparative measurements.

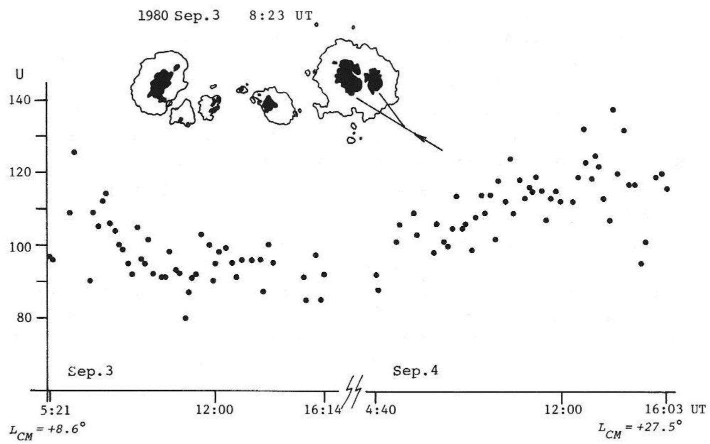

Fig.8 An example of a series of area measurements of a large double-umbra (U) over two days.

(The arrow in the drawing marks the measured double-umbra. Cf. additional pictures of the spot in L.Gesztelyi and L.Kondás, *Publ.Debrecen Obs. 5*, pp.133-143, 1983 and L.Gesztelyi, *Adv.Space Res. 4*, No.7, pp.19-22, 1984 = *Heliophys.Obs.Debrecen Preprint No.1.*)

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Appendix 3

L. Dezső

AN ACCOUNT OF THE GREENWICH PHOTOHELIOGRAPHIC RESULTS OF 1874-1976 AND OF DEBRECEN'S FIRST CATALOGUE OF 1977

1. INTRODUCTION

A certain periodicity in the occurrence of sunspots, found by H.Schwabe from his persistent systematic observations during the years of 1826-1843, became known worldwide through A.Humboldt's *Cosmos* (Volume 3) in 1851. Shortly after this, in 1852, E Sabine (London), R.Wolf (of Zürich) and A.Gautier (Genève) discovered independently a connection between Schwabe's period and the Earth's magnetic field, which was principally supported by John Lamont's (München) earlier announcement (1851) on a periodicity of about 10.3 years in the annual average daily ranges of magnetic declination. Herewith, from that time on the initial steps have been taken in investigations of relationships on solar-terrestrial physics.

However, in the middle of the 19th century, there was a lack of adequate solar data. As this became widely realized, new initiatives in recording sunspots were undertaken in several places. R.C.Carrington was the first who started and successfully carried out a long series of detailed observations and determined "the Elements of Position of the Pole and Period of Rotation" of the Sun numerical data of which are still used up to now. His results were published in *Observations of the Spots on the Sun from November 9, 1853, to March 24, 1861* (London, 1863).

He remarks in the "Concluding Section" that "... in future observations of the Sun, ... the methods of photographic registration ... are obviously those to be followed, rather than the method of sketching and time observations which I have employed, while those improved processes were not yet worked out" (p.248).

The photographic registration were already recommended in 1854 by John Herschel and this "led to the preparation of the Kew photoheliograph"