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MERGING TWO DATA SETS OF HEMISPHERIC SUNSPOT NUMBERS

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Abstract. First results on merging two data sets of hemispheric sunspot numbers – from the Kanzelhöhe Solar Observatory and the Skalnaté Pleso Observatory – for the time span 1977 – 1978 are presented. A total coverage of 86% was reached for the merged data set. In order to have a homogeneous time series, the daily sunspot numbers for the full disk from both observing stations were normalized to the international relative sunspot number of the day. The derived hemispheric sunspot numbers from Kanzelhöhe and Skalnaté Pleso Observatory show very high correlations ($r \gtrsim 0.95$), and the estimated data noise yields significant differences only for small values of sunspot numbers. These outcomes demonstrate the high potential of the applied merging procedure, and are the basis for an ongoing project to derive hemispheric sunspot numbers back to the year 1945 using sunspot drawings from Kanzelhöhe and Skalnaté Pleso Observatory.

Key words: Sun – sunspots – solar cycle – N-S asymmetry

1. Introduction

The well-known phenomenon of north-south asymmetries of solar activity was studied extensively in the past using various solar activity indices, e.g., sunspot areas, flare occurrence, distribution of prominences/filaments, CMEs or green corona intensity. However, relative sunspot numbers subdivided into the two hemispheres were only rarely utilized for this purpose (e.g., Swenson, 1986, Koyama, 1985, Temmer et al., 2002b). The main reason is that an appropriate data set is not available at present. In fact there exist only two publicly available data sets of hemispheric sunspot numbers: the international hemispheric sunspot numbers from SIDC compiled since the year 1992 until present[1] and the Kanzelhöhe catalogue of hemispheric sunspot numbers from 1975 to 2000 (Temmer et al., 2002a)[2]. The latter data set is longer but is only of partial data coverage due to the limitation of one observing station. The former one consists of daily data with 100% coverage from a network of observing stations but is still very short (only partially covering solar cycles no. 22 and 23, respectively).

In order to fill this gap we work on a new set of hemispheric sunspot numbers combining data from two observatories covering the period from 1945 until present. The goal of this paper is to test the procedure of data merging on sample data from a limited time span (1977 – 1978).

2. Data

Daily hemispheric sunspot numbers for the time span 1977 – 1978 are derived from two observatories which regularly take sunspot drawings: the Kanzelhöhe Solar Observatory – KSO (IGAM, University of Graz, Austria) and the Skalnaté Pleso Observatory – SPO (Astronomical Institute, Tatranská Lomnica, SAS, Slovakia). A catalogue of hemispheric sunspot numbers for the time span 1975 – 2000 based on KSO observations has been prepared by Temmer et al. (2002a). The mean data coverage is 73% for the KSO data set over the 25-year interval and 59% for the SPO data set over the longer interval 1944 – 2002. Fig. 1 plots the number of missing days per month for each data source. For the time span 1977 – 1978 considered in this paper, the KSO and SPO data sets consist of 526 and 387 daily data, respectively. The total coverage (i.e. observations from at least one of the two stations) during 1977 to 1978 is 625 days (86%).

[1] http://sidc.oma.be/html/dailyssn.html

[2] http://www.uni-graz.at/igam-sophy/daily_RnRs/

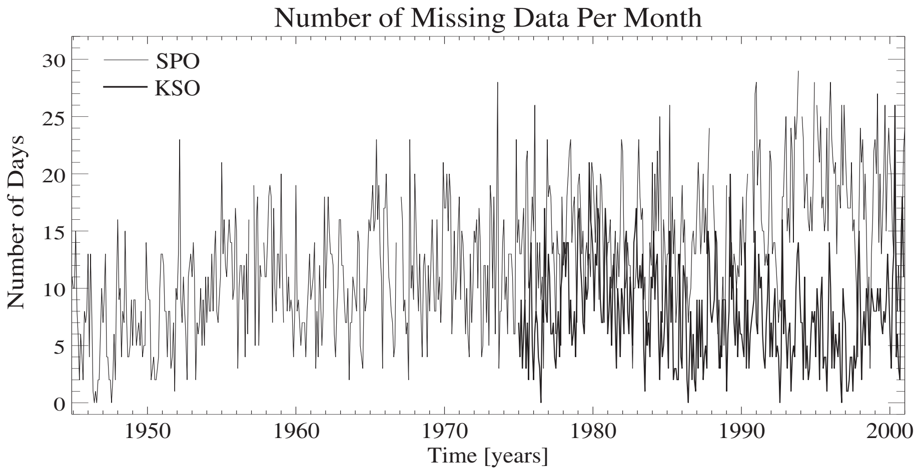

Figure 1: Monthly number of missing days, i.e. days which are not covered by KSO (thick line) and SPO data (thin line), respectively.

For deriving the hemispheric sunspot numbers from SPO observations, the same procedure as in Temmer et al. (2002a) for KSO hemispheric sunspot numbers was applied. From daily sunspot drawings, the sunspot number is counted separately for the northern and the southern hemisphere. These raw values are then normalized in such a way that their sum equals the international daily sunspot number (of the full disk). This procedure ensures that the derived hemispheric sunspot numbers are consistent with the international ones from SIDC which are available since 1992.

3. Results

The KSO and SPO data during common observation days were used to determine the relation between the two different data sets. Correlation coefficients, standard errors and the coefficients of linear least square fits applied to the hemispheric sunspot numbers considered separately as well as together are given in Table 1. In Fig. 2, SPO versus KSO hemispheric sunspot numbers together with the resulting linear fits are plotted for all common days. The high correlation coefficients ($r \gtrsim 0.95$) and the slopes derived from the linear fits, which are very

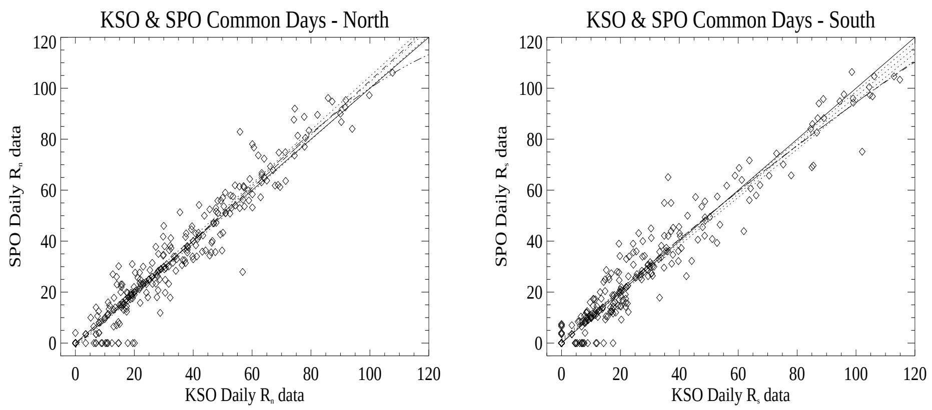

Figure 2: Scatter plots of daily hemispheric sunspot numbers for the northern and southern hemisphere, respectively. SPO data are plotted against KSO data for 290 common days during 1977 – 1978. The dotted lines show the linear fit derived from SPO versus KSO data and the corresponding $\pm 1\sigma$ interval. The solid line marks reciprocal relation.

close to 1, confirm the very good agreement between both data sets. Moreover, as can be seen from Fig. 2, deviations from a one-to-one correspondence are mainly $\lesssim 10$. Differences in sunspot numbers of about ± 10 are likely due to unequal observations, i.e. a small active region is registered by one observing station but not by the other.

The excellent agreement of the KSO and SPO data justifies to directly merge both data sets without any further transformation. When data from both stations are available, the mean of both SPO and KSO hemispheric sunspot numbers is used. Otherwise, when solely data

Hemisphere	Constant	Slope	Correlation	Std. error
N	-1.183 ± 0.622	1.039 ± 0.016	0.967	6.39
S	$+1.107 \pm 0.509$	0.957 ± 0.014	0.967	6.33
N&S	$+0.227 \pm 0.397$	0.991 ± 0.011	0.967	6.42

Table I: Parameters derived from the linear fits applied to SPO versus KSO daily hemispheric sunspot numbers considering both hemispheres separately (N, S) as well as together (N&S).

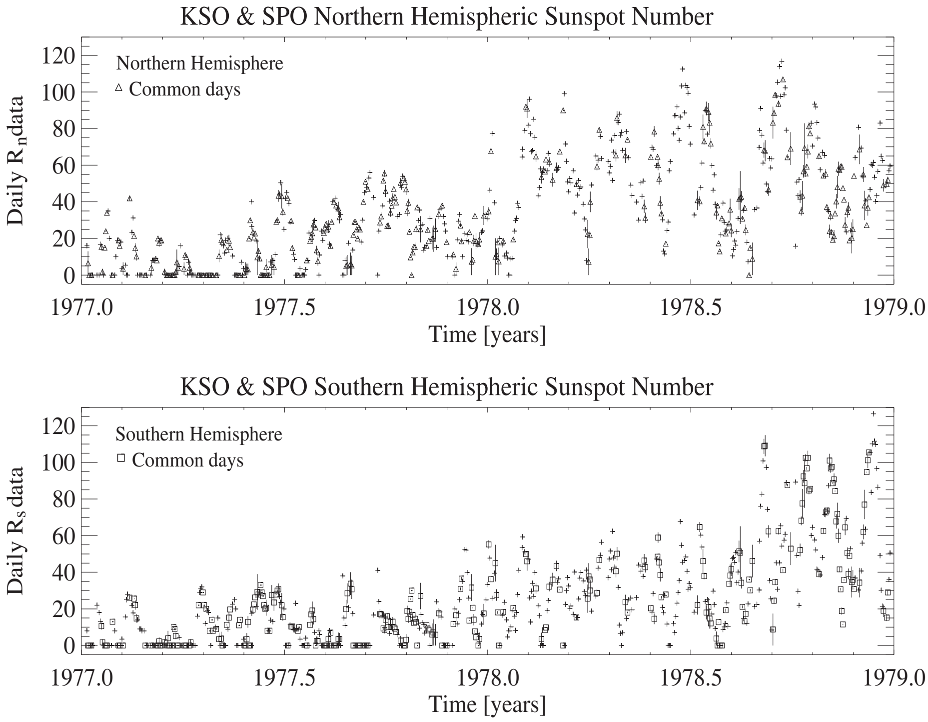

Figure 3: Evolution of the merged sunspot numbers. Mean values during common days are denoted by triangles (squares) for the northern (southern) hemisphere. Error bars give the difference between KSO and SPO data.

from one station are available, these are used for the merged data set.

The merged KSO and SPO data divided into the northern and southern hemispheres are plotted in Fig. 3. For common observation days we determined the relative difference of the SPO and KSO hemispheric sunspot numbers, which can be used as an estimate of the data noise. The relative differences are given by the absolute differences of the KSO and SPO data divided by their mean value. Fig. 4 indicates that in general the differences between KSO and SPO data are small. Significant deviations are found solely for sunspot numbers $\lesssim$40.

For days in which from none of both stations data are available (14% during 1977 – 1978) linear interpolation is applied. This gives us the final data set of hemispheric sunspot numbers plotted in Fig. 5.

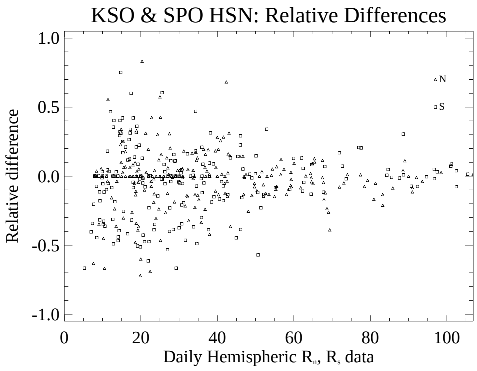

Figure 4: Relative differences of KSO and SPO hemispheric sunspot numbers against their mean value during common days.

The plot reveals N-S asymmetries on a daily basis (top panel). After smoothing out these variations (bottom panel), a significant N-S asymmetry is seen: from about 1977.5 to 1978.6 the activity in the northern hemisphere is much more dominant than that in the southern hemisphere.

4. Conclusions

Merging observations from two stations (SPO and KSO) enabled us to prepare an improved data set of hemispheric sunspot numbers increasing the total coverage from 72% (KSO hemispheric sunspot number catalogue for 1977 – 1978) to 86%. The hemispheric sunspot numbers derived from both sources are highly correlated ($r \gtrsim 0.95$). Independent estimation of data noise showed sufficiently low relative differences between KSO and SPO hemispheric sunspot numbers. The applied normalization procedure ensures that these data can be compiled with the international hemispheric sunspot numbers from SIDC which are available from 1992 onwards, to finally provide us with a long and homogeneous time series.

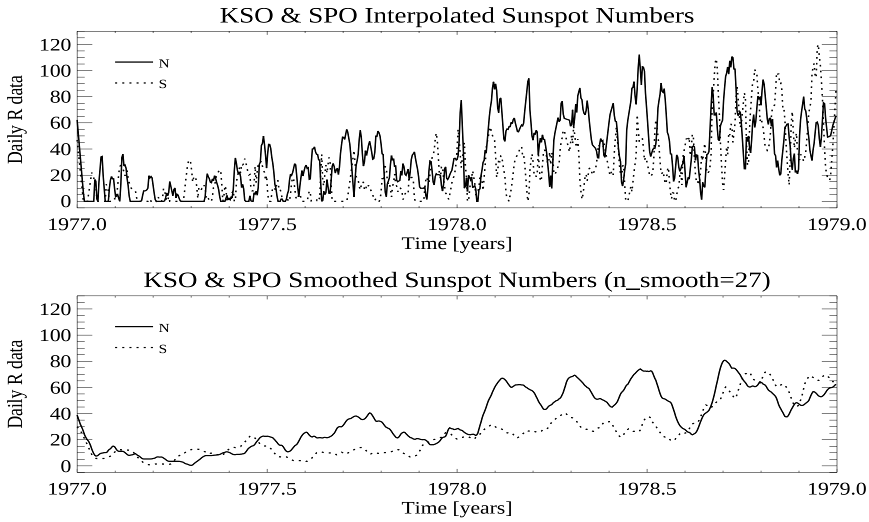

Figure 5: Final set of merged and interpolated hemispheric sunspot numbers (top panel) and smoothed with a 27-day running mean (bottom panel).

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References

Koyama, H.: 1985, Observations of Sunspots 1947–1984, Kawadeshoboshinsha, Tokyo

Swinson, D.B., Koyama, H., Saito, T.: 1986, *Solar Phys.* **106**, 35

Temmer, M., Veronig, A., Hanslmeier, A.: 2002a, *Astron. Astrophys.* **390**, 707

Temmer, M., Veronig, A., Rybak, J., Hanslmeier, A.: 2002b, in ESA-SP 506, ESA, Noordwijk, The Netherlands, 859