CATALOGUE OF HEMISPHERIC SUNSPOT NUMBERS $R_N$ AND $R_S$: 1975–2000

M. Temmer, A. Veronig, and A. Hanslmeier

Institute for Geophysics, Astrophysics and Meteorology, University of Graz, Universitätsplatz 5, A-8010 Graz, Austria, E-mail: manuela.temmer@uni-graz.at

ABSTRACT

Sunspot drawings are provided on a regular basis at the Kanzelhöhe Solar Observatory, Austria, and the derived relative sunspot numbers are reported to the Sunspot Index Data Center in Brussels. From the daily sunspot drawings, we derived the northern, $R_n$, and southern, $R_s$, relative sunspot numbers for the time span 1975–2000. In order to accord with the International Sunspot Numbers $R_I$, the $R_n$ and $R_s$ have been normalized to the $R_I$, which ensures that the relation $R_n + R_s = R_I$ is complied. For validation, the derived $R_n$ and $R_s$ are compared to the international northern and southern relative sunspot numbers, which are available since 1992. The regression analysis performed for the period 1992–2000 reveals good agreement with the International hemispheric Sunspot Numbers. The monthly mean and the smoothed monthly mean hemispheric Sunspot Numbers are compiled to a catalogue. In addition, the daily hemispheric Sunspot Numbers are made available via Internet.

1. INTRODUCTION

The relative sunspot numbers $R$ are a measure of solar activity on the entire disk of the Sun. The relevance of the relative sunspot numbers lies in particular in the fact that they represent one of the longest time series of solar activity indices available. Thus, relative sunspot numbers provide the foundation of a continuous data set for research on the solar cycle and its long-term variations. $R$ is defined by

$$ R = k (10g + f), \quad (1) $$

where $g$ is the number of observed sunspot groups, $f$ the number of spots and $k$ is an observatory-related correction factor.

Historically it can be noted that $R$ is the modified form of the so-called Wolf index or Wolf number, which was defined without the correction factor $k$. The Wolf number was introduced in 1848 by Rudolph Wolf, who was the first to compile daily Sunspot Numbers. The original intention of introducing the correction factor $k$ in about 1882 by Wolf's successors at the Zürich Observatory was to convert the actual daily measurements to the scale originated by Wolf (cf. Waldmeier 1961). Waldmeier (1961) compiled actual records from the Zürich Observatory in coordination with various additional observing stations as well as data collected by Wolf (1858). Beginning from 1700, yearly means of relative sunspot numbers are listed; starting with 1749 also monthly mean Sunspot Numbers are given. This compilation of the so-called Zürich relative sunspot numbers is one of the most commonly used databases of solar activity (see also Hoyt & Schatten 1998a, b). In 1981, the Zürich relative sunspot program was replaced by the Sunspot Index Data Center (SIDC) in Brussels, which is the World Data Center for Sunspot Indices (see also Rishbeth 1991; Ruttenber & Rishbeth 1994).

Figure 1. Example of a sunspot drawing from the Kanzelhöhe Solar Observatory. Date: 21st of March 2000.
Figure 2. Scatter plots of the daily (top panels), monthly mean (middle panels) and smoothed monthly mean (bottom panels) hemispheric Sunspot Numbers for the northern (left panels) and the southern (right panels) hemisphere. Calculated hemispheric Sunspot Numbers from KSO, \( R_n,_{KSO} \) and \( R_s,_{KSO} \), are plotted against the International hemispheric Sunspot Numbers provided by the SIDs, \( R_n,_{SIDC} \) and \( R_s,_{SIDC} \), for the period 1992–2000.

In contrast to the relative sunspot numbers, the hemispheric Sunspot Numbers \( R_n \) and \( R_s \) were not compiled on a regular basis and are not available before 1992. From January 1992, the daily \( R_n \) and \( R_s \) as well as monthly means have been compiled by the SIDS (Cugnon 1997). However, for several research purposes, in particular the study of North-South (N–S) asymmetries of solar activity, hemispheric Sunspot Numbers are needed for longer periods. With the present catalogue we aim to provide hemispheric Sunspot Numbers for at least two full solar cycles (21 and 22). In general, we derived the hemispheric Sunspot Numbers for the period 1975–2000. The data beginning from January 1992 are used for an estimation of the consistency of the derived \( R_n \) and \( R_s \) with respect to the International \( R_n \) and \( R_s \) compiled by the SIDs.

At the Kanzelhöhe Solar Observatory (KSO), Austria, daily sunspot drawings (see Fig. 1) have been provided since 1947 within the framework of solar surveillance programs. The daily provisional relative sunspot numbers that are derived from the drawings are compiled and reported to the SIDs in Brussels. The KSO is part of collaborating observatories all over the world from which provisional Sunspot Numbers are collected and averaged in an advanced form. The finally derived numbers are published as the definitive International Sunspot Numbers \( R_i \) by the SIDs. A detailed description of the calculation of the definitive International Sunspot Numbers, which in particular has to ensure that the scaling with respect to the Zürich Sunspot Numbers is maintained, is given in Cugnon (1997) as well as online at http://sidc.oma.be/index.php. Details concerning the KSO and its observing capabilities can be found in Steiniger et al. (2001). Furthermore, the sunspot drawings and other observational data are online available at the KSO web page at http://www.kso.ac.at/.

2. DATA GATHERING AND REGRESSION ANALYSIS

We evaluated the sunspot drawings of the KSO from January 1975 to December 2000. Within this period, 6900 observation days were available, which represents a data coverage of \( \sim 73\% \). (Missing sunspot drawings are due to bad seeing conditions at the location of the KSO.) From this data set we derived daily, monthly mean and smoothed monthly mean hemispheric Sunspot Numbers. For each observation day, the Sunspot Number was counted separately for the northern and southern hemisphere, respectively. From this “raw” hemispheric Sunspot Numbers we determined the relative fraction of the northern and southern component, \( n \) and \( s \). The final hemispheric Sunspot Number, \( R_n,_{KSO} \) and \( R_s,_{KSO} \), was obtained by multiplying the northern and southern fractions with the definitive International Sunspot Number, \( R_i \), of the day. With this procedure we ensure that the derived hemispheric Sunspot Numbers are nor-
Table 1. Cross-correlation coefficients (Corr.), the parameters obtained from the linear least-squares fit (const., slope), and the standard error between the fitted and original data (StE) of the performed regression analysis (cf. Fig. 2).

<table>
<thead>
<tr>
<th>Corr. Linear Fit</th>
<th>StE</th>
</tr>
</thead>
<tbody>
<tr>
<td>const.</td>
<td>slope</td>
</tr>
<tr>
<td>daily N</td>
<td>0.991</td>
</tr>
<tr>
<td>daily S</td>
<td>0.991</td>
</tr>
<tr>
<td>monthly N</td>
<td>0.992</td>
</tr>
<tr>
<td>monthly S</td>
<td>0.998</td>
</tr>
<tr>
<td>sm.mon. N</td>
<td>0.999</td>
</tr>
<tr>
<td>sm.mon. S</td>
<td>0.999</td>
</tr>
</tbody>
</table>

To circumvent the problem that possible outliers of the monthly mean data bias the preceding and succeeding months when calculating the smoothed monthly mean hemispheric Sunspot Numbers, we reversed the sequence of averaging and smoothing the data. First we smoothed the daily hemispheric Sunspot Numbers with a 365 days running average. Subsequently we calculated the monthly means of this annually-smoothed daily data. The bottom panels in Fig. 2 show the scatter plots of the derived smoothed monthly Sunspot Numbers for the northern and southern hemisphere versus the smoothed monthly mean hemispheric Sunspot Numbers from the SIDC. Both panels clearly reveal that the derived smoothed data closely match the SIDC data (see also the summary of the regression analysis in Table 1). In particular, the influence of the outliers of the northern monthly mean Sunspot Numbers is almost eliminated. In Figure 3 we plot the time evolution of the derived smoothed monthly mean hemispheric Sunspot Numbers (solid line) for the period 1992–2000, which closely resemble the corresponding data from the SIDC (dashed line).

In Fig. 4 we plot the derived smoothed monthly mean hemispheric Sunspot Numbers for the period 1975–2000. Fig. 5 shows the daily Sunspot Numbers of the northern and southern hemisphere. An analysis of the N-S asymmetry based on the hemispheric Sunspot Numbers regarding the total activity during the considered period as well as dominant rotational periods is presented in Temmer et al. (2002a, b).

3. ORGANIZATION OF THE CATALOGUE

The monthly mean and the smoothed monthly mean hemispheric Sunspot Numbers for the period 1975–2000 have been compiled into a catalogue (see Temmer et al. 2002a). The catalogue is available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/390/707. The daily data of northern and southern Sunspot Numbers are online available at http://www.uni-graz.at/igams/www/daily_sns. The organization of the catalogue is described in the following.
• 1st column: Year and month (Months with less than 11 observation days are marked with an asterisk (*) to note that the statistical significance of the derived monthly data is low.)

• 2nd column: Monthly mean northern Sunspot Numbers

• 3rd column: Monthly mean southern Sunspot Numbers

• 4th column: Smoothed monthly mean northern Sunspot Numbers (365 days running average followed by monthly mean calculations)

• 5th column: Smoothed monthly mean southern Sunspot Numbers (365 days running average followed by monthly mean calculations)

Figure 4. Smoothed monthly mean hemispheric Sunspot Numbers for the time span 1975–2000. The thick line indicates the northern, the thin line the southern Sunspot Numbers derived from the KSO data.

Figure 5. Daily northern (top panel) and southern (bottom panel) Sunspot Numbers for the time span 1975–2000.

ACKNOWLEDGMENTS

The authors thank the former and present staff of the KSO for performing and making available the sunspot drawings, and also for helpful comments. We especially thank F. Vogler for his effort in scanning the KSO sunspot drawings and thus making the work more easy. M.T., A.V. and A.H. gratefully acknowledge the Austrian Fonds zur Förderung der wissenschaftlichen Forschung (FWF grant P15344) for supporting this project.

REFERENCES

Temmer M., Veronig A., Rybák J., Hanslmeier A., 2002b, these proceedings