70 YEARS OF SUNSPOT OBSERVATIONS AT KANZELHÖHE OBSERVATORY

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Abstract. During World War II the German Airforce established a network of observatories, among them the Kanzelhöhe Observatory (KSO), which would provide information on solar activity in order to investigate the conditions of the Earth’s ionosphere in terms of radio-wave propagation. Solar observations began already in 1943 with photographs of the photosphere and drawings of sunspots, plage regions and faculae, as well as patrol observations of the solar corona. Since 1944 relative sunspot numbers were derived, these relative numbers agree with the new International Sunspot Number (ISN, SILSO World Data Center, 1945–2015; Clette et al., 2014) within ≈ 10%. However, revisiting the historical data, we also find periods with larger deviations. There were two main reasons for these deviations. On the one hand major instrumental changes took place and the instrument was relocated to another observation tower. On the other hand there were periods of frequent replacements of personnel. In the long term, the instrumental improvements led to better image quality, and a trend towards better seeing conditions since the year 2000 was found.

Key words: sunspots - full-disk - relative number - observations

1. Introduction

In the 1930s Mögel and Dellinger (Dellinger, 1935) found that flares (“solar eruptions”) can increase the density of low-altitude layers of the ionosphere, which leads to an absorption of short-wave radio waves causing blackouts of radio communications. The “Deutsche Luftwaffe” (German Airforce) founded a network of observatories in the Alps, Zugspitze, Schauinsland, and Wendelstein in Germany and Kanzelhöhe in Austria, to collect knowledge about these effects, as they became dependent on radio communication, due to the increasing importance of airplanes and submarines. The location (N 46°40.7′, 13°54.1′, altitude 1526 m) of Kanzelhöhe Observatory (KSO) was chosen because the area was reachable throughout the year.
by cable car, it had good observing conditions (Eckel and Lauscher, 1937), and it was located near a city (Villach). The scientific work was guided under the direction of K. O. Kiepenheuer from the Fraunhofer Institute in Freiburg, Germany (now “Kiepenheuer Institut”, KIS). In autumn 1941 the construction works were started and in 1943 observations with state of the art equipment began. More detailed information about the history of the solar research during this period has been given by Seiler (2007) and Kuiper (1946).

After WW II the observatory was reorganized and affiliated with Graz University as part of a new institute. The official confirmatory was in the year 1949 after the founding of the second republic (Jungmeier, 2014; Jungmeier et al., 2014).

In the beginning, during WW II, the main communication and data transfer took place within the German network, but in 1948 international cooperation began and data was transferred to Greenwich, Zurich, Freiburg, Paris, Moscow, and other international data centres.

2. Instruments and Observations

1943 – 1973

The observatory was build with two observation towers, a detached northern tower and the southern tower. In the northern tower a coronagraph (Comper and Kern, 1957, \(d/f = 11/165 \text{ cm}\)) was installed until 1947. On this coronagraph a telescope was mounted piggyback for producing sunspot drawings with a diameter of 15 cm.

In the southern tower a heliostat from Zeiss (see Figure 1) reflected the sunlight down to the laboratory (located in the basement) where all instruments were situated. The two flat mirrors of the heliostat had a diameter of 30 cm and were guided by a synchronous motor. The mirrors were originally silver-coated, which was not a long-lasting solution. Therefore in 1950 the mirrors were coated by an aluminum evaporation deposition, which was protected by a thin silica film. In the 1960s the guiding of the heliostat was improved by installing a remote control and servomotors. In the end of 1947 the drawing telescope was moved below the heliostat and the size of the projection increased to 25 cm.
Figure 1: The Zeiss-Heliostat (right) with two flat mirrors of 30 cm in diameter mounted in the southern tower was in use from 1943 until 1973. The sunlight was reflected down to the laboratory in the basement, where the drawing table and the spectrohelioscope were installed (left).

1973 – TODAY

Since 1973 all observations have been transferred to the patrol instrument in the northern tower. This instrument comprised of three (later four) refractors on a common equatorial mounting. The diurnal movement is tracked by a microprocessor system and additionally corrected by the image position of the camera images. The following instruments were mounted on the patrol instrument:

**Hα telescope:** in the beginning it was equipped with a miniature film adapter that was controlled automatically so that every four minutes one image was taken. The film rolls, each consisting of about 1000 images, were completely digitized in 2007 (Pötz, 2008). In 1998 the recording technology was changed to CCD cameras (Hanslmeier et al., 2003), which were upgraded in 2005 and 2010 (Pötz et al., 2015).

**Drawing device:** the objective lens of the old vertical telescope was reused and a new zoom optics system was built in order to obtain the same size of the projected solar disc as before (25 cm). A great benefit was the arrangement of the drawing device directly on the declination axis of the telescope, which minimizes the forces applied by the observer onto the telescope motion (see Figure 2).

**White-light telescope:** beginning with 1989 (Pettauer, 1990) images were
captured on large size film (13 cm × 18 cm). The data and films are currently being digitized (Pötzi, 2010). In 2007 a CCD camera replaced the old system, which was again replaced in 2015 by a camera with more greylevels. **Magneto Optical Filter:** this device (Cacciani *et al.*, 1999) was installed between 1999 and 2002, producing intensity images, dopplergrams, and magnetograms. **Ca II K telescope:** This telescope was installed in 2010; the filter is centered at 393.37 Å and it was operated from the beginning with a CCD camera (Hirtenfellner-Polanec *et al.*, 2011).

### 3. Sunspot Numbers at KSO and Comparison to ISN

The sunspot groups are classified according to the Zurich classification scheme (Waldmeier, 1955), which describes the evolution of sunspot groups. The relative sunspot number is then obtained by counting the individual sunspots $s$ and sunspot groups $g$ as $R = k(10 \cdot g + s)$ (cf. Fig. 3). The reduction factor $k$ is a weighting factor that accounts in particular for the different telescopes, which is necessary when combining the data of different observatories. Until 2015, before the new ISN was introduced, this factor was set to match the original 8 cm telescope used by Rudolf Wolf in Zürich.
Figure 3: Detail of a sunspot drawing from Oct. 24 2014, when a very big sunspot group was visible. From the number of groups and individual spots the relative number is computed. In this drawing there are 6 groups and 91 spots.

(Waldmeier, 1961). For the ISN a reduction factor for each telescope is calculated, regardless of the observer and the observational conditions. But in principle for each observer an individual reduction factor can be applied.

For the yearly averaged (13 month smoothed) relative numbers a single $k$-factor for the telescope is sufficient, as the seeing quality and the observer characteristics shall level out over the year, but for a daily comparison this factor has to be more flexible. In order to compare the daily relative numbers obtained at Kanzelhöhe to ISN $k$-factors for each observation quality level were introduced. The quality depends on the sharpness of the projection, the specifications for these have been described by Kiepenheuer (1964). The values range from 1 to 5 depending on the details visible in the photosphere or on the size of the image motion due to the atmosphere, 1 is for exceptional conditions.

The $k$-factors were calculated the first time in 1948 and then recalculated...
in 1958 (Haupt et al., 1959), in 1979 (Schroll, 1979) and again in 2016 because of the transition to the new ISN and some discrepancies between KSO number and ISN. E.g. in 2016 the $k$ factors were:

<table>
<thead>
<tr>
<th>Quality</th>
<th>1</th>
<th>1-2</th>
<th>2</th>
<th>2-3</th>
<th>3</th>
<th>3-4</th>
<th>4</th>
<th>4-5</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k$-factor</td>
<td>0.75</td>
<td>0.81</td>
<td>0.86</td>
<td>0.93</td>
<td>1</td>
<td>1.08</td>
<td>1.16</td>
<td>1.26</td>
<td>1.36</td>
</tr>
</tbody>
</table>

For the computation of these $k$ factors a large number of observations is necessary in order to get a good statistical distribution. Therefore it takes years until new factors can be generated after some instrumental change. In 2016 the values have been obtained from 11200 drawings, that were made since 1973 on the patrol instrument. Such a large number ensures that there are enough drawings in each quality class and the long time – 3 solar cycles – gives a good distribution of relative numbers.

Fig. 4 shows a comparison between KSO numbers and the ISN. At first glance they seem to agree very well (lower plot), but when plotting the ratio between both numbers, it becomes obvious that there are some periods with larger deviations from the ISN. In order to find the reasons for these
discrepancies, the KSO internal activity reports (KSO, 1946–2000) were searched through. The letters in the upper plot denote the periods which were of interest:

a Due to the increase of the size of the projected image from 15 cm to 25 cm in Nov. 1946, a larger number of sunspots could be identified in the observations. As the projection changed from the piggyback instrument on the coronagraph to the projection in the southern tower in the year 1948 with a stable drawing table the quality of the observation further improved.

b According to the activity reports there were problems with the guiding of the heliostat in 1948 and problems with the aluminum coating of its mirrors. In the year 1950 a completely new coating of the mirrors enhanced the brightness and therefore the contrast and quality of the projection.

c The drift between 1956 and 1962 cannot be explained by any instrumental changes. In 1958 new correction factors were calculated as it became clear that there was some deviation; these factors were higher and may be the reason for the extension of the drift until 1962.

d Between 1965 and 1968 major construction works were carried out at the observatory, the observations were even stopped for some months in 1966, 1967, and 1968. A fluctuation of observers began in 1968, when three new observers were employed. These fluctuations lasted until 1975 with a total of ten new observers.

e New reduction factors were used from June 1979, which led to smaller sunspot numbers. The new k-factors for qualities 3 to 5 were about 10% lower than the old factors; this deviation maybe also be due to the fact that there is also some uncertainty in the ISN series during this time as the Zurich observatory was closed and the transition to Locarno occurred (Clette et al., 2014).

f New observers were employed, but also sudden image quality changes happened. Two observers went into retirement; their eyesight may have become worse causing some drift in the sunspot number, similar to the reason for the Locarno drift discussed in Clette et al. (2014).
The image sharpness of the projection is denoted on every drawing. The mean image sharpness seems to have increased during the last 70 years, with the transition to the new patrol instrument in 1973 the conditions became more stable.

From 2009 new observers came to the observatory and were introduced into the observational work. New observers tend to underestimate the image quality which results in higher sunspot numbers.

4. The Observation Conditions at KSO

In Fig. 5 a sharp transition in the seeing conditions with the change from the heliostat to the patrol instrument can be seen, the conditions became much more stable from 1973 on. In the first observation years the instrumental changes (15 cm to 25 cm diameter, coronagraph to heliostat) and problems with the mirrors caused unstable quality indices. The bad seeing conditions at the end of the 1950s cannot be explained, but in this time also the KSO relative numbers were too high, we assumed that the quality estimations were not correct during this period. In the 1960s there were larger construction works at the observatory, it was even not operating for a few months. In the 1990s the seeing conditions became worse as a result of the Pinatubo volcano eruption in June 1991 (Otruba, 1993). From then on, the quality increased, as there where no changes in the vicinity of the observatory and at the instrument, we may speculate that climatic changes
led to different atmospheric influences, but according to Auer et al. (2007) massive changes in temperature and air humidity in southern Austria had already begun in 1970.

5. Discussion

To get correct and comparable daily relative numbers for a single observatory a good statistics, i.e. a long observation series, is necessary in combination with observers that have a lot of experience. Although the instructions for the estimation of the image quality are very clear, observers need some time to be experienced enough. Another problem came up in the last 20 years with additional data available over the internet from other sources and even from space observations, that are not polluted by the atmosphere. So observers are now able to see, what in the ideal case should be seen on the Sun, and they may then draw more spots then they would have done without any help. Also new observers show some peculiarities, on the one hand they estimate the quality too low and on the other hand they try to do their best and find more spots then their colleagues - this results in too large relative numbers.

When applying yearly $k$ factors not only changes of the instrumentation, but also changes in the vicinity (observatory building, forest, streets, ...) have to be taken into account and noted somewhere for a later inspection of the data.

A more detailed description and result statistics can be found in Pötzi et al. (2016).

Acknowledgements

The internal activity reports were of great help, but some details were only discovered by the help of Hermann Haupt and Thomas Pettauer, who have shaped the observatory through their work since the early 1950s and 1960s, respectively.

References


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