Under Development: 01 September 2013 (WFD)

Readme: Sunspot Numbers

"Today, much more sophisticated measurements of solar activity are made routinely, but none has the link with the past that sunspot numbers have"
(J.A. McKinnon)

Sunspot Numbers

Sunspots are temporary phenomena on the photosphere of the Sun that appear visibly as dark spots compared to surrounding regions. They are caused by intense magnetic activity, which inhibits convection by an effect comparable to the eddy current brake, forming areas of reduced surface temperature. They usually appear as pairs, with each sunspot having the opposite magnetic pole to the other. Although they are at temperatures of roughly 3000–4500 K (2700–4200 °C), the contrast with the surrounding material at about 5,780 K (5,500 °C) leaves them clearly visible as dark spots, as the luminous intensity of a heated black body (closely approximated by the photosphere) is a function of temperature to the fourth power. If the sunspot were isolated from the surrounding photosphere it would be brighter than the Moon. Sunspots expand and contract as they move across the surface of the Sun and can be as small as 16 kilometers (10 mi) and as large as 160,000 kilometers (100,000 mi) in diameter, making the larger ones visible from Earth without the aid of a telescope. They may also travel at relative speeds ("proper motions") of a few hundred meters per second when they first emerge onto the solar photosphere. Manifesting intense magnetic activity, sunspots host secondary phenomena such as coronal loops (prominences) and reconnection events. Most solar flares and coronal mass ejections originate in magnetically active regions around visible sunspot groupings. Similar phenomena indirectly observed on stars are commonly called starspots and both light and dark spots have been measured. (derived from Wikipedia)

The SunSpot Number (SSN) is a commonly used index of solar activity. The daily sunspot number was first introduced in 1848 by the Swiss astronomer, Johann Rudolph Wolf. His method, which is still used today, counts the total number of spots visible on the face of the sun and the number of groups into which they cluster, because neither quantity alone satisfactorily measures sunspot activity. The relative sunspot number is an index of the activity of the entire visible disk of the Sun. It is determined each day without reference to preceding days. Each isolated cluster of sunspots is termed a sunspot group, and it may consist of one or a large number of distinct spots whose size can range from 10 or more square degrees of the solar surface down to the limit of resolution (e.g., 1/25 square degree). The relative sunspot number is defined as

$$R = K\,(10g + s)$$

where g is the number of sunspot groups and s is the total number of distinct spots. The scale factor K (usually less than unity) depends on the observer and is intended to normalize the conversion to the scale originated by Wolf. The provisional daily Zurich relative sunspot numbers, R_z, were originally based upon observations made at Zurich and its two branch stations in Arosa and Locarn, Switzerland. Beginning January 1, 1981, the Zurich relative sunspot number program was replaced by the Solar Influences Data analysis Center (SIDC). The determination of the provisional International Sunspot Numbers R_i results from a statistical treatment of the data originating from more than twenty-five observing stations. These stations constitute an international network, with the Locarno station as the reference station, to

guarantee continuity with the past Zurich series of R_z. The definitive International Sunspot Numbers, R_i, are evaluated by a similar method based on a network of observing stations selected for their high number of observations, their continuity during the whole year and an existing series of observations for past years. Also taken into account is the stability of the K monthly factors with reference to the Locarno station. These relative sunspot numbers are now designated R_i (International) instead of R_z (Zurich). Monthly and yearly averages of the daily SSN are calculated in a straightforward manner.

The daily sunspot number has little, if any, relationship to ionospheric variability. However, the most widely used Ionospheric Index, R12, is derived from the daily sunspot numbers. The R12 index is a twelve-month smoothed relative sunspot number. To calculate the R12 index for July 2010 add half of the Jan 2010 value plus the sum of the Feb through Dec 2010 values plus half of the Jan 2011 value and by divide the sum twelve:

$$[(n1/2)+(n2+n3+.....n11+n12)+(n13/2)]/12$$

where n1 = Jan 2010, n7 = July 2010 and n13 = Jan 2011. Today, much more sophisticated measurements of solar activity are made routinely, but none has the link with the past that sunspot numbers have.

AVAILABLE DATASETS

Dataset: International Sunspot Numbers (1610 – Present)

Description – The relative sunspot number is an index of the activity of the entire visible disk of the Sun. It is determined each day without reference to preceding days. Each isolated cluster of sunspots is termed a sunspot group, and it may consist of one or a large number of distinct spots whose size can range from 10 or more square degrees of the solar surface down to the limit of resolution (e.g., 1/25 square degree). The relative sunspot number is defined as R = K (10g + s), where g is the number of sunspot groups and s is the total number of distinct spots. The scale factor K (usually less than unity) depends on the observer and is intended to effect the conversion to the scale originated by Wolf.

Dataset Provider: Solar Influences Data analysis Center (SIDC), Royal Observatory of Belgium, Av. Circulaire, 3 - B-1180 Brussels Belgium. (POC: Frederic Clette)

- Daily sunspot numbers – Tables; Listing (1818-Present)
- Monthly mean SSN – Table; Listing (1749-Present)
- Year mean SSN – Table; Listing (1700-2009)
- Smoothed monthly mean SSN – Table; Listing (1749-Present)

Dataset Status: Active

Dataset: American Relative Sunspot Numbers (1944 – Present)

Description – Dataset consists of tables and listings of the American Relative SunSpot Number (SSN) provided by the American Association of Variable Solar Observers (AAVSO). Tables include the daily relative SSN (RA' from 1951 and RA before 1951) along with the calculated monthly and yearly means. Similarly, the listings are of daily RA and RA' plus the monthly and years means. Beginning with 1951, the observations collected by the Solar Division, AAVSO, have been reduced according to a new procedure, such that only high quality observations of

experienced observers are combined into RA'. Observatory coefficients for each of the 23 selected observers were recomputed on data for 1948-1950, years when there was a wide range of solar activity. Otherwise, the procedure is that outlined in "Publication of the Astronomical Society of the Pacific," "61," 13, 1949. The scale of the American numbers in 1951 will differ from that of the reports for earlier years because of these changes, and the new series is designated RA' rather than RA.

Data Provider: American Association of Variable Solar Observers (AAVSO), 49 Bay State Rd. Cambridge, MA 02138, USA. (POC: Rodney Howe)

- Monthly Bulletin – Bulletin (1964-Present)
- American Relative SSN – Tables; Listing (1944-Present)

Dataset Status: Active

Dataset: Group Sunspot Numbers (1610 – 1995)

Description – Dataset consists of a large number of tables for the Group SunSpot Number (*Rg*) aas provided by D.V Hoyt. *Rg* values were derived to provide a homogeneous record of solar activity from 1610 to 1995. Care was taken that the long-term changes are more self-consistent than are the changes using the Wolf Sunspot Numbers. Procedures used to develop this dataset are described in Hoyt and Schatten [*1998*]. The files can be grouped to five categories as listed below.

Provider: D.V. Hoyt [*TBD*]

- Daily Values and Means – Tables (1964-Present)
- Standard Deviations – Files (1610-1995)
- Daily Input Data – Files (1610-1995)
- Number of Observers – Files (1610-1995)
- Documentation Files – Files (1610-1995)

Dataset Status: Inactive

Dataset: Hemispheric Sunspot Numbers (1992 – Present)

Description – Text

Provider: Dataset Provider: Solar Influences Data analysis Center (SIDC), Royal Observatory of Belgium, Av. Circulaire, 3 - B-1180 Brussels Belgium. (POC: Frederic Clette)

- Hemispheric SSN (*Rn*/*Rs*) – Tables; Lists (1992-Present)

Dataset Status: Active

Dataset: Predicted Sunspot Numbers (2009 – 2020)

Description – The traditional McNish-Lincoln technique is used to predict the future smoothed sunspot numbers of a solar cycle. The technique compares the amplitude of a cycle in the month of prediction with the amplitude of the mean cycle at the same epoch; that being the same month as measured from the preceding sunspot minimum. It then uses this difference in amplitudes to predict the cycle amplitude in future months. (after Hildner and Greer [1989]). A review of other predictive techniques is discussed in Hathaway et al. [1999]

Under Development: 01 September 2013 (WFD)

Provider: NOAA National Geophysical Data Center, 325 Broadway, Boulder, CO 80305, (POC: Justin Mabie)

- Predicted SSN – Table (2009-2020)

Dataset Status: Active

Dataset: Swiss-Wolf Sunspot Numbers (2011 – Present)
Description – Founded in Zurich in 1992 Rudolf Wolf Society (CT) seeks the continuation of Rudolf Wolf in the 19th Century reasoned series of sunspot numbers and the maintenance and utilization of scientific Wolf's estate.

Provider: Rudolph Wolf Society (RWG), POC [*TBD*]

- Swiss-Wolf SSN – Bulletin (2011 – Present)

Dataset Status: Active

Dataset: Solar Cycle Parameters (1610 – present)

Description – Various parameters characterizing the solar cycle are listed. When observations permit, the date selected as either the cycle minimum or maximum is based in part on an average of the times extremes are reached in the monthly mean sunspot number in the smoothed mean sunspot number, and in the monthly mean number of spot groups alone. Two more measures are used at the time of sunspot minimum: the number of spotless days and the frequency of occurrence of "old" and "new" cycle spot groups. (*Note: this analysis technique is under review.*)

Provider: NOAA National Geophysical Data Center, 325 Broadway, Boulder, CO 80305, (POC: Justin Mabie)

- Minima & maxima of smoothed SSN – Table (1610-Present)

Dataset Status: Active

Dataset: Ancient Sunspot Numbers (165 BC – 1715)

Description – Text

Provider:

- Eddy Reports – Table (1610-1715)
- Wittman – Abstract; Catalog (165 BC-1684)

Dataset Status: Inactive

References

Cliver, E.W., F. Clette and L. Svalgaard (2013), Recalibrating the Sunspot Number (SSN): The SSN Workshops, *Cent. Eur.Astrophys.Bull., 37*, 401–416.

Eddy, J.A. (1976), The Maunder Minimum", *Science, 192*, 1189-1202.

Hathaway, D.H., R.M. Wilson and E.J. Reichmann (1999), A Synthesis of Solar Cycle Prediction Techniques, *J. Geophys. Res., 104*, 22,375-22,388.

Hathaway, D.H., R.M. Wilson and E.J. Reichmann (2002), Group Sunspot Numbers: Sunspot Cycle Characteristics, *Solar Phys., 211*, 357-370.

Hildner, E. and M.S. Greer (1989), Reliability of the McNish-Lincoln Technique for Predicting Solar Cycle Amplitude in Timing, in Solar-Terrestrial Predictions: Proceeding of a Workshop at Leura, Australia, 16-20 October 1989, 689-695.

Hoyt, D.V. and K.H. Schatten (1998), Group Sunspot Numbers: A New Solar Activity Reconstruction, Solar Phys., 181, 491-512.

Li, K.J., P.X. Gao, L.S. Zhan, X.J. Shi and W.W. Zhu (2008), On the Asynchronization of Hemispheric High-Latitude Solar Activity, *R. Astron. Soc., 391*, L34-L38.

Li, K.J., P.X. Gao, L.S. Zhan and X.J. Shi(2009), The Long-Term Hemispheric Sunspot Activity, Astrophys. J., 691, 75-82. DOI: 1088/0004-637X/691/1/75

Shapley, A.H.(1947), Publ. Astron Soc. Pacific, 61, p. 358-xxx.

Taylor, P.O. (1985), Computation of the American Relative Sunspot Numbers, *J. AAVSO, 14*, 28-32.

Vaquero, J.M. (2007), Historical Sunspot Observations: A Review, Adv. Space Res., 40, 929-941. DOI: 10.1016/j.asr.2007.01.087

Vaquero, J.M. and R.M. Trigo (2013), Revised Group Sunspot Number Values for 1640, 1652 and 1741, Solar Phys., DOI: 10.1007/s11207-013-0360-2

Waldmeier, M. (1961), The Sunspot Activity in the Years 1610-1960, Zurich.