GROUP SUNSPOT NUMBERS: A NEW SOLAR ACTIVITY RECONSTRUCTION

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(Received 21 July 1997; accepted 1 October 1997)

Abstract. In this paper, we construct a time series known as the Group Sunspot Number. The Group Sunspot Number is designed to be more internally self-consistent (i.e., less dependent upon seeing the tiniest spots) and less noisy than the Wolf Sunspot Number. It uses the number of sunspot groups observed, rather than groups and individual sunspots. Daily, monthly, and yearly means are derived from 1610 to the present. The Group Sunspot Numbers use 65 941 observations from 117 observers active before 1874 that were not used by Wolf in constructing his time series. Hence, we have calculated daily values of solar activity on 111 358 days for 1610–1995, compared to 66 168 days for the Wolf Sunspot Numbers. The Group Sunspot Numbers also have estimates of their random and systematic errors tabulated. The generation and preliminary analysis of the Group Sunspot Numbers allow us to make several conclusions: (1) Solar activity before 1882 is lower than generally assumed and consequently solar activity in the last few decades is higher than it has been for several centuries. (2) There was a solar activity peak in 1801 and not 1805 so there is no long anomalous cycle of 17 years as reported in the Wolf Sunspot Numbers. The longest cycle now lasts no more than 15 years. (3) The Wolf Sunspot Numbers have many inhomogeneities in them arising from observer noise and this noise affects the daily, monthly, and yearly means. The Group Sunspot Numbers also have observer noise, but it is considerably less than the noise in the Wolf Sunspot Numbers. The Group Sunspot Number is designed to be similar to the Wolf Sunspot Number, but, even if both indices had perfect inputs, some differences are expected, primarily in the daily values.

1. Introduction

For more than 100 years the Wolf or Zürich Sunspot Numbers have served as the primary time series to define solar activity since 1700. This time series was derived by Rudolf Wolf who worked on the problem from 1848 to 1893 and devoted more than 3000 pages to describing his data and techniques. His time series was maintained by his successors at Zürich.

The Wolf Sunspot Numbers before 1893 (henceforth R_Z) have remained unchanged since their original publication (Wolf, 1873; Waldmeier, 1947; McKinnon, 1986). These numbers were derived by hand using a single primary observer whose missing days were filled by secondary observers. The time series has no error bars associated with it. Finally, a considerable portion of the older observations were not located by Wolf in his research. The purpose of this paper then is fourfold: (1) identify observations not included in the R_Z study, (2) digitize them so they are available to all, (3) derive a new and more homogeneous time series, and (4) provide random and systematic error estimates.

The paper will first describe the collection and digitization of the data. Then we will describe Wolf's method of reconstructing solar activity followed by a

Solar Physics **179:** 189–219, 1998.

description of our approach. This is followed by an error analysis of our time series, called the Group Sunspot Numbers (R_G). The Wolf Sunspot Numbers are then compared to the R_G numbers on the daily, monthly, yearly, and secular time scales. These comparisons will illustrate the differences between R_G and R_Z and show why R_G tracks solar behavior more uniformly on the long-term than do the R_Z's. Finally we will summarize our results and offer some suggestions on how our results might be improved.

Our major conclusion is that solar activity for 1700 to 1882 is lower than that given by Wolf by 25 to 50%. Activity is poorly determined before 1653, accurately found for 1654 to 1727, is uncertain by up to 15 to 20% or is unknown for many years from 1728 to 1800, is determined to about a 5% accuracy for 1800 to 1850, and is known to a 1 to 2% accuracy for 1851 to the present.

2. The Collection and Tabulation of the Observations

The first step in reconstructing solar activity is the collection and digitization of raw solar observations. An original impetus to this study arose when it was noticed that sunspot observations existed on days when there was no R_Z. This suggested that Wolf may have missed some observations in his 45 years of collecting them.

In our approach we only digitized the number of sunspot groups, for reasons to be explained shortly. The first step was digitizing the observations published by Wolf and his successors in the Zürich journal first called 'Mitteilungen über der Sonnenflecken' and later called 'Astronomische Mitteilungen'. This journal was published from 1858 to 1947. Because some observations are embedded in the text, the journal was repeatedly scanned to get all the observations. This journal supplied 224 503 observations from 306 observers. Later we received a copy of a tabulation of Wolf's observations from the Zürich Observatory called 'Sonnenflecken-Statistik 1610–1900'. This manuscript confirmed that we had not overlooked any observations.

The next step was locating modern observations after 1947 and searching journals and unpublished archives. Wolf documented the journals he examined so we concentrated upon journals he missed such as 'Raccato di Opusculi Scientifici a Filogiri', where Musano's observations for 1739–1742 reside. More than 20 serials were examined concentrating on Italian, Dutch, and English journals that Wolf neglected.

Other major sources of material were unpublished observations. These were located by using modern bibliographies listing library holdings and by an occasional journal reference to a manuscript. We obtained microfilm or xerox copies of manuscripts when possible, but also visited the libraries at the University of Aarhus, the Royal Astronomical Society, the Royal Society, Cambridge University, Hamilton College, and the St. Petersburg State Library in Russia. Rare books were examined primarily at the Naval Observatory Library and the Library of Congress. Several correspondents also sent us early data from manuscript or journal sources.

All this searching, which took more than three years, proved very fruitful. If, for example, we consider only those observers active before 1874 when the Royal Greenwich Observatory started observing, we have 330 observers with 147 462 observations (see Appendix 1 for a complete listing of observers). In contrast, Wolf had 213 observers with 81 521 observations. Thus, our searching yielded 117 new observers with 65 941 observations or about an 80% increase in observations over what Wolf located. Because early observations are often scarce, most of our effort went into searching for early observers. Modern observations were not neglected though and here we tried to get as many as ten observers per year, a goal which was mostly achieved.

The final database we collected has 455 242 observations from 463 observers. From 1610 to 1995 there are 140 986 days, so we have on average about three observations per day. Unfortunately, the observations are not evenly spaced in time, but we do get an estimate of solar activity on 111 358 days, or 79% of the days, using this database. In comparison the R_Z's have 66 138 daily values with earliest daily values being in 1818.

It is worth spending a few words describing the different types of observers. These can be placed in several different categories described below:

(1) *Zürich-recorded observers.* These observations are tabulated in the 'Astronomische Mitteilungen' as mentioned above. They cover the period from 1610 to 1947 and consist of 306 observers with 224 503 observations. There are occasional typographical errors, which, when obvious, were corrected. These observations plus the unpublished observations for 1948 to the present form the raw database for the Wolf or Zürich Sunspot Number time series.

(2) *'New non-Zürich' observers.* These are the observations we collected from journals and unpublished archives as described above. There are 163 new observers with 230 739 observations. Appendix 1 lists all the observers, with their beginning and ending years of activity and the number of days they observed.

(3) *'Effectively new' observers.* Wolf relied upon correspondents to examine manuscripts for him and to send their interpretation of the results to him. In 1893, just before he died, he was sent tabulations of the observations by Thaddeus Derfflinger for 1802 to 1824 and Schwarzenbrunner for 1825 to 1830. These observations were never incorporated in the R_Z's and so may be labeled as effectively new.

(4) *'Enhanced' observers.* In some cases Wolf did not acquire all the observations from a particular observer. We suspect our database will prove eventually to have the same deficiency. Observers where we obtained more observations than Wolf

did include Riccioli, Hevelius, Picard, La Hire, Stancarius, Flamsteed, E. Manfredi, Rost, Alischer (called Alishez by Wolf), Horrebow, William Herschel, Julius Schmidt, and Gustav Spoerer.

(5) *'Partially recorded' observers.* For some observers, not all their observations were published, such as Wolf, for whom our database is still missing observations in the 1850s. Other observers, such as the San Miguel Observatory in Argentina, are not complete because we could not locate a complete run of the serials. In both these cases and similar cases, these omissions do not substantially affect the final solar activity reconstruction since there are many other observations that can be used. However, improvements in our database can still be made.

(6) *'Corrected' observers.* In a couple of cases the tabulations sent to Wolf appear to have been erroneous. The observations by Pastorff from 1819 to 1833 are a prime example. These observations, as tabulated by Wolf, have very high numbers of groups because A. C. Ranyard who made the tabulation confused sunspot groups and individual sunspots. We re-examined the original drawings and made a new interpretation of the observations as discussed by Hoyt and Schatten (1995). In Appendix 1, Ranyard's and hence Wolf's interpretation is listed as 'Pastorff/Wolf'. Another corrected observer is Horrebow. 'Horrebow/Wolf' is Wolf's interpretation courtesy of Prof. D'Arrest, 'Horrebow' is our interpretation, and 'Horrebow – Version 2' is Horrebow's own interpretation of his observations made for just a few years.

(7) *'Vague' observers.* Some observers are 'vague' in one way or another so their observations could not be used. These observers generally comment on whether spots are present or not, but do not estimate the number of groups. They are commented upon in our bibliography, but are not listed in Appendix 1. Vague observers include Schroter, Hahn, Sturmer, and many others.

(8) *'Summary' observers.* Some observers do not supply details of their daily observations. This is particularly true among modern observers who publish only monthly means. These observers are mentioned in our bibliography as a reminder that their daily observations may yet be found. Another type of summary observer are those who comment that they have seen no sunspots from one date to another, despite actively observing the Sun. These days are filled in as days with no sunspots, but if another observer reports a sunspot in these intervals, his observations take precedent over the summary observer. There are about 20 of these observers, mostly before 1700.

(9) *'Misplaced' observers.* Another type of observer are those whose observations we know exist, but repeated efforts to locate the observations failed to locate them. Prominent observers in this category include J. G. Fink (active 1788–1816),

Soemmering (active 1826–1829), and Chevallier (active 1847–1849). Locating these observations could improve our solar activity reconstruction.

(10) *'Lost' observers.* Some observers we know were active and their observations were either definitely lost such as those of Horrox (active 1638) whose manuscripts were burned. For some observers, such as Scheiner, who observed sunspots on a nearly daily basis from 1611 to 1633, only a small portion of his observations survive in *Ursa Rosina* and his other publications. Another observer in this category is Alischer who kept a sunspot diary called 'Diaria macularum solarium' that may have observations from 1727 to 1746 when hardly any observations were made. Lost manuscripts also include observations by Picard (before 1665), Fogel (1662–1670) Weigel (1662–1664), Weickmann (1666–1667), and Siverus (1675–1690).

(11) *'Unknown' observers.* Despite considerable searching, there undoubtedly remain observers completely unknown to us. There could be manuscripts or journal articles that we have failed to identify.

(12) *'Poor' observers.* As many observations were collected as possible before the analysis began. Some observers, as will be seen later, may be classified as poor and are dropped entirely from the analysis. Most of these observers miss too many sunspot groups. One observation series, 'Mt. Wilson, Center of Disk,' by design misses sunspot groups near the limb, but these observations are omitted from any solar activity reconstruction. It is included in the database for completeness for possible use in other studies.

To summarize we have found many observations, but the search has not been as exhaustive as we would like. Appendix 1 summarizes the observers and observations we have found. A bibliography with comments that is part of our database identifies many of the problems discussed above. In Figure 1, we show the number of days each year that we have derived an estimate of solar activity from 1610 to 1995. We have complete or nearly complete coverage from about 1800 to 1995 and from 1645 to 1727. From 1610 to 1644 and from 1728 to 1799 observations become sparse in many years and there are six years (1636, 1637, 1641, 1744, 1745, and 1747) for which no reports of sunspot observations exist.

3. Rudolf Wolf's Techniques for Reconstructing Solar Activity

The Wolf Sunspot Number was originally developed by Rudolf Wolf of Zürich in the 1850s. It has been called the Wolf Sunspot Number, Zürich Sunspot Number, or International Sunspot Number at various times. Here we will refer to it as the Wolf Sunspot Number (R_Z). Wolf defined the sunspot number, R_Z, as

$$R_Z = k(10g + n) , \quad (1)$$

where g is the number of sunspot groups, n is the number of individual sunspots, and k is a correction factor for each observer. The R_Z for each day is calculated by using only the input from one observer. If the primary observer could not make an observation, then secondary, tertiary, etc., observers were used until as many days as possible were filled.

The primary observer for the R_Z's are Staudacher (1749–1787), Flaugergues (1788–1825), Schwabe (1826–1847), Wolf (1848–1893), Wolfer (1893–1928), Brunner (1929–1944), Waldmeier (1945–1980), and Koeckelenbergh at Brussels from 1980 to the present. The order of secondary and higher-order observations is not made explicit but can sometimes be deduced by careful analysis of the raw data and processed numbers.

The observing factors k were determined by ratioing the primary observers to Wolf and then by ratioing secondary and tertiary observers to the primary observers. Values of k for any observer can vary with time to match the unvarying k's of the primary observers. No error bars for these values of k were calculated, so the R_Z's have no error bars associated with them.

After filling as many observing days as possible, Wolf still had gaps in his data. These gaps occur first in the interval 1818 to 1848, where nonetheless missing days are few enough to be manageable. For 1817 and earlier, the number of missing days were so great that Wolf only tabulated monthly means. For many months from 1749 to 1818 and for fewer months after 1818, there are no observations. Wolf filled these months by interpolation in some cases, such as February 1824. Some missing months were filled by using magnetic needle observations* and others by calculating the missing months by a linear regression technique. It is important to realize the R_Z's are a mixture of direct sunspot observations and calculated values.

Wolf also provides yearly values from 1700 onwards. He did not publish earlier yearly means because of a lack of data and his doubts that many years were entirely free of sunspots during the grand sunspot minimum now called the Maunder Minimum. Missing years such as 1744, 1745, and 1747 are fill values and are not based upon any sunspot observations.

Finally, in collecting data, Wolf did not travel to view the original observations, but rather relied upon correspondents to analyze and send the results to him. As shown in an earlier paper (Hoyt and Schatten, 1995), the quality of these interpretations was sometimes poor since the distinction between the definition of a group and individual spot was not always clear to his correspondents .

* 'Magnetic needle observations' are measurements of 'geomagnetic activity' related to aurora, and hence CMEs, flares, solar activity, sunspots, etc. – the direction of a magnetic needle (on the Earth's surface) made during the course of a day. When the Sun is active the needle varies more than when the Sun is quiet due to solar-wind-carried magnetic fields, etc. These observations were made mostly between 1780 and 1860 in different European cities.

4. Technique for Deriving Group Sunspot Numbers

The technique used here has some parallels to Wolf's approach, but also has some significant differences. We define a sunspot index called the Group Sunspot Number (R_G) as follows:

$$R_G = \frac{12.08}{N} \sum k_i' G_i \ , \tag{2}$$

where G_i is the number of sunspot groups recorded by the ith observer, k_i' is the ith observer's correction factor, N is the number of observers used to form the daily value, and 12.08 is a normalization number chosen to make the mean R_G's identical with the mean R_Z's for 1874 to 1976 when the Royal Greenwich Observatory (RGO) actively made sunspot observations using Equation (2). The normalization number can be interpreted as saying the average sunspot group consists of about two spots (i.e., 2.08), but that is not the basis for chosing its value. This number will vary slightly depending on how many observations are used and so differs from our previously reported value of 11.93 (Hoyt and Schatten, 1994), because of the addition of more than 100 000 observations since that preliminary study. This technique for deriving sunspot number is used because 90% of the variance is caused by changes in the number of groups and many observers specify only the number of groups rather than both the number of groups and number of individual spots (see Schatten and Hoyt, 1994).

k', the observer's correction factor to place him on the same scale as RGO, is defined as 1.000 for our primary observer, RGO ($i = 332$ in Appendix 1). Observers who overlap the RGO can be directly compared to RGO. We form a ratio by dividing the total number of sunspot groups observed by the comparison observer and by RGO, limiting the ratio to those days when both observers saw one or more sunspots. This ratio is k'. The quality of the comparison is defined as equal to the number of intercomparison days divided by the quantity $(|1 - k')|$. Thus, a high-quality secondary observer is one who made many comparisons to the primary observer (RGO) and whose measurements are most similar to those by RGO.

These secondary observers allow us to compare observers further back in time to RGO. If the value of k' for a secondary or any higher order observer is less than 0.6 or greater than 1.4, that observer is not used for any intercomparisons. The value of k' for a tertiary observer is found by weighing their ratios to the secondary observers by the quality of the secondary observer. The process above is repeated for 4th, 5th, 6th, and 7th level observers. This technique maximizes the contribution of the best and most active observers and minimizes the number of intermediate observers between RGO and observer for whom k' is being calculated. It utilizes all the information we have rather than a selected subset. Finally, because multiple intercomparison paths are followed, both the mean k' and its standard deviation can be calculated. These values are tabulated in Appendix 1. Our method of deriving

k' is basically identical to that used by Wolf in deriving his k values, although our weighting scheme is more complex. Although the daily sunspot groups follow a Poisson distribution, the daily ratios of one observer to another tend to follow a Gaussian distribution, allowing both Wolf and ourselves to use this method of determining k'.

This technique works well to about 1800 by covering most observers and gives some answers for observers in the 1700's such as Horrebow. However, because of the scarcity of observations from 1730 to 1800 (see Figure 1), comparisons during this period become difficult. Therefore, we established Horrebow as the primary observer for this period so we could calculate k' for more observers. For Horrebow, we successively tried values of k' of 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, and 1.8 and calculated the k' values for all possible observers by the technique described above. These groups of k' values were then compared to the group of k' values derived starting from RGO. The best mean value for k' for Horrebow was found to be 1.565 defined by the intersection of the two curves in Figure 2. At this intersection the mean k' derived starting from RGO and from Horrebow are the same. This intersection is interpreted as giving the best fit value for k' for Horrebow. Other interpolation schemes, whether linear or nonlinear, would give a value of k' for Horrebow between 1.5 and 1.6. Several different interpolations were tried by varying the allowable range of intermediate k' values that could be used (plots not shown). The number of observers for which k' could be derived starting at RGO and at Horrebow averaged to 121 observers for these different interpolations. The mean value of k' for Horrebow equaled 1.565 to within 1% and was virtually independent of the choice of allowable k' values for intermediate observers. The same technique was followed for the observations before 1730 where Plantade was chosen as the primary observer with a calculated k' of 1.107.

A number of observers, particularly in the early years, are isolated from all other observers. Most often they contribute a single observation day when no other observers were active. In these cases, we assigned them a k' value of 1.255 ± 0.112 based on the mean of group of modern observers (see Schatten and Hoyt, 1994). Sometimes there are clusters of observers isolated from all other observers. For example, the earliest observers in the 1600s are isolated. Here we treated *Galileo* as the primary observer and assigned him a k' value of 1.25 so as to make this cluster more internally self-consistent. 3.5% of all the observations are isolated. Since 1700, 1.2% of the observations are isolated. Of this 1.2%, 0.5% are isolated because they were made on days with no sunspots. Most of the isolated observers before 1700 are isolated because they were made on zero sunspot days. Thus, the solar activity reconstruction is insensitive to the value of k' for isolated observers.

Once the k' values for all observers are calculated, the solar activity reconstruction can begin by calculating the daily means using all available observers for that day. Before doing so, poor observers are excluded with $k' < 0.6$ and $k' > 1.4$. This criterion was applied only after 1848 when observations are plentiful and we can afford to discard observers. About 40 observers are discarded in all. Before

1848 Pastorff's observations as tabulated by Wolf are discarded along with one observation by F. G. W. Struve. Next, the daily means and standard deviations are the calculated. If a value used to calculate the mean is more than two standard deviations away from the mean, that value is discarded, and a new mean and standard deviation for that day are calculated. Gaps of up to 4 days for an active Sun and 6 days for a quiet Sun are filled by linear interpolation. These interpolations will give correct answers to within 1 group 95% of the time.

In Figure 3, we show a plot of the yearly mean R_G's and R_Z's. These numbers along with estimates of their sytematic errors and the Wolf Sunspot Numbers are tabulated in Appendix 2. The systematic errors in the Group Sunspot Numbers consist of four components: (1) errors arising from missing observations, (2) errors arising from uncertainties in the values of k', (3) errors arising from random errors in the daily values, and (4) errors arising from drifts in the k' values.

Errors arising from missing observations are easy to compute and are the dominant error term. For each year with less than 365 (366 in leap years) days of observations, we took the same subset of observed days and calculated the yearly means for the 146 years where complete coverage of the year is available (i.e., 1850 to 1995) and compared the subset mean to the completely sampled mean. The absolute mean percentage difference gives an estimate of the systematic error arising from missing observations. This systematic error is plotted as function of the number observed days in Figure 4. For 20 or more days of observations (D), the error E follows a linear relationship:

$$E = 0.217 - 0.00059D\,.$$

As D approaches 365 or 366, this systematic error approaches zero. For D less than 20, erratic results are found, so we conclude no reliable yearly mean can be found in such circumstances. Twenty-five out 386 years thus can not have their yearly means accurately found, even though individual days and months in those years may have reliable values.

Errors arising from uncertainties in k' were evaluated by deriving the mean uncertainties for five selected eras: (1) 1610–1653, (2) 1653–1730, (3) 1731–1797, (4) 1798–1850, and (5) 1851–1995. These eras have the common property that they can be classified as poorly observed, partly observed, or fully observed. Observers in these eras tend to form large nearly isolated clusters of observers in all but the case of 1798 to 1850. This era is broken out separately since most of its years are not fully observed. Errors for these eras were found to be equal to 5%, 7%, 24%, 7%, and 2%, respectively.

Each daily mean has an uncertainty associated with it of about 12%. This uncertainty is nearly constant time, rising to about 14% circa 1880 when the meaning of a group was not the same for all observers. The systematic error arising from these daily random errors was calculated as 0.12 divided by the square root of the number of observing days. For a completely sampled year, this error is 0.63%.

The final source of systematic error is possible secular changes in k' for the observers. k' has one value for observer which applies to all his observations. Errors arising from changes in k' cannot be calculated in any way known to us, but are probably small since drifts by one observer will tend to be canceled out by opposite drifts from other observers. Thus, this error is taken as zero in our error analysis.

The final systematic error is the root-mean-sum of the errors above. The errors are plotted in Figure 5. These errors are less than 10% everywhere except for 1728 to 1799. Observations are scarce then so poor sampling and near isolation of the observations both combine to drive the error up to values of the order of 15–20%.

5. Some Comparisons of the Wolf and Group Sunspot Numbers

Numerous comparisons between the Group Sunspot Numbers and Wolf Sunspot Numbers can be made. In the last third of the paper, we present sample comparisons between R_G and R_Z based upon four time scales: daily, monthly, and yearly values, and secular trends. These comparisons are made to help elucidate some of the reasons the two time series differ.

5.1. Daily Values

The daily R_G's have a mean value tabulated along with their standard deviation and number of observers used to form the mean. The R_Z's have a daily value derived from one observer with no error estimate. The R_Z's have daily values starting in 1818, but complete daily coverage does not start until 1849. The R_G's have daily values whenever possible. There is nearly complete daily coverage from 1645 to 1727 and from 1847 to the present. There is substantial daily coverage from 1797 to 1846. The coverage is illustrated in Figure 1.

The daily R_G's are more homogeneous than are the daily R_Z's. This can be illustrated by a couple of specific examples, such as the year 1829. In Figure 6, the R_G's and R_Z's for this year are plotted and in Figure 7 we show the differences between the two time series. The R_G's have complete coverage for this year using eight observers, two of whom Wolf did not have access to. The R_Z's have 291 days. There are a number of upward spikes in the R_Z's that are not present in the R_G's. For 1829 Wolf used Schwabe as his primary observer. One of his secondary observers was Pastorff. For each spike, Schwabe had no observation, but Pastorff did. These spikes are caused by Pastorff's observations which are not homogeneous with Schwabe's observations. In Figure 6, one can see that the day-to-day fluctuations in the R_Z's are greater than the R_G's everywhere.

The example in Figure 6 shows how improper merger of observers leads to unrealistic fluctuations in the R_Z's. Other fluctuations arise because observations were taken on hazy days so small sunspot groups are missed. This effect shows up as sudden one day drops in solar activity. Other effects must be going on as well as an examination of five days in February 1860 shows (Table I).

Table I

R_Z and R_G for 5 days in February 1860. The R_Z varies erratically up and down, but the R_G are more steady. The number of groups observed by eight observers during this interval are given. Wolf had access to all the observations except those by Howlett and Shea. The reason for the large value on 10 February is unclear as well as the reason for low value on 9 February. Many such unexplained non-solar variations appear in the R_Z's.

Date	R_Z	R_G	Schwabe	Schmidt	Wolf	Carrington	Coast survey	Weber	Howlett	Shea
8 Feb.	103	82	6						4	
9 Feb.	52	68	5	7		6	7	5	2	2
10 Feb	161	47	2	5			5	3		3
11 Feb	71	51			3			4		4
12 Feb	103	51	4			4		3		4

The day-to-day fluctuations of the R_Z's have a solar component and a component caused by the observers. The component caused by the observers can be called 'observer noise'. For R_Z, this observer noise is greater than the observer noise in the R_G's, particularly for the earlier years. Gradually, the derivation of the R_Z's improves and by the 1950s both the R_Z's and R_G's have the same levels of observer noise. It is our conclusion that the R_G's are more homogeneous on the time scale of days. However, we would like to add that R_Z and R_G are two distinct indices of solar behaviour so some differences will occur even if the measurements were error free. The primary objective in deriving R_G was to obtain a self-consistent index of the long-term solar activity.

5.2. MONTHLY VALUES

Monthly means can be formed when daily values are available. Generally three or four widely separate days within a month are adequate to form a monthly mean. Often though there are no observations at all. For the R_G's these missing months are filled with a value of -99. Monthly means are formed for all other cases and the number of days used to form these monthly means are given too, so we leave it to the user of the numbers to evaluate their usefulness.

From January 1749 to the present, there are 84 missing months in the R_G time series. In contrast the published R_Z's have complete monthly coverage for this interval. Wolf used two procedures to fill in missing values: (1) linear interpolation, and (2) using magnetic needle observations and linear regression model to fill in missing months. It is not always clear which procedure is being followed for each filled month.

We have chosen not to fill the monthly means. The R_G's are a pure time series in that are based solely upon telescopic observations of sunspot groups. The R_Z's are a mixed time series based upon telescopic observations and magnetic needle observations.

Table II

The monthly mean R_Z's and R_G's for January to March 1824. This shows that monthly interpolations are not always reliable and that the R_G's have more data to form monthly means

Month	R_Z days	R_Z	R_G days	R_G
January	3	21.7	10	15.7
February	0	10.8	29	0.5
March	21	0.0	31	0.0

After 1800 the R_G's have no missing months, but the R_Z's have many interpolated months. For example, February 1824 is interpolated in the R_Z's to give a value of 10.8. For the R_G's, 29 days of observations are available, so its monthly mean can be calculated to be 0.5, which is substantially different from the interpolated value. The January to March 1824 interval is summarized in Table II.

Finally, the month-to-month differences for the R_G's are less than for the R_Z's, which is an indication of less observer noise in the R_G's.

5.3. Yearly Values

R_Z's have yearly values since 1700 or for 296 years. R_G's have yearly values from 1610 to 1995 or 386 years. Of these 386 years, six years had no observations and so do not have a yearly value. Another 20 years have 20 or fewer observations, so their yearly means are unreliable. An 'unreliable mean' is one whose uncertainty is greater than 25%. Years that have no value or an unreliable value are 1610, 1614, 1615, 1623, 1630, 1636, 1637, 1640, 1641, 1723, 1724, 1731, 1732. 1734. 1737, 1738, 1739, 1741, 1743, 1744, 1745, 1746, 1747, 1748, 1759, 1783, 1784, 1789, 1790, 1792, 1793, and 1794. In general then we would say solar activity is poorly known or unknown for 1610–1641, for 1731–1748, and for 1789–1794. For 1642 to 1730, for 1750 to 1788, and for 1795 to the present, the R_G's are well determined. We would recommend ignoring values before 1642 and using interpolated or modeled values for 1731 to 1748 and from 1789 to 1794. Values between 1642 and 1653 may also be suspect because although we have reports of low activity then, it is not certain yet that these reports are true.

In Appendix 2, we tabulate the yearly mean R_G's along with their one-standard-deviation uncertainty and number of days observed during the year. For comparison, the R_Z yearly means are listed too. Most of the differences in the two time series occur before 1882 when the sunspot counting technique of Wolf was altered according to Hossfield (1997), but some significant differences occur even for recent years. For example, for 1980 the R_G is 141.1 but the R_Z is 154.6 or 9.6% higher. The Ottawa Sunspot Number for 1980 is 142.3. For the adjacent years, 1979 and 1981, the R_Z and R_G agree to within 1%. Why then do they differ for

1980? There is no simple answer to this question. For nine of the twelve months, the R_Z's exceed the R_G's. For three of the months, the R_Z's exceed the R_G's by more than 10%: (1) February (+23%), (2) April (+43%), and November (+20%). Focussing on April, the R_Z daily values range from 95 to 252, while the R_G's range from 83 to 142. On 13 April, the R_Z peaks at 252, the R_G equals 128, the American Sunspot Number is 213, and the Ottawa sunspot number is 176.3. The number of recorded groups are 8 (SEL), 8 (Rome), 10 (Catania), 11 (Mt. Wilson), 7 (Taipei), 8 (NAO, Japan), and 9 (Koyama). Ignoring correction factors for the observers, this corresponds to 8.7 groups. With correction factors used, we estimate 10.6 groups, meaning on average observers missed counting two, presumably small, groups. Yet the R_Z of 252 for this day implies about 20 groups should be present. One possibility is that the groups present on that day were extraordinarily complex having of the order of 15 individual spots per group. This explanation is not quite satisfactory since the discrepancies between the R_Z and R_G appear to occur erratically and not systematically, since other periods with high activity and presumably complex groups agree with each other. The raw numbers used to generate the R_Z's in these cases are not available in the published literature so the differences cannot be resolved. Again, we emphasize that R_G and R_Z are similar solar indices, so even in ideal circumstances their daily numbers will not agree.

Despite these differences, more than 90% of the years after 1900 have R_G's and R_Z's that agree to within 10 units. The disagreements may arise from some inhomogeneity in the R_Z's or the R_G's, or it may be expecting too much to have identical R_Z's and R_G's since the two indices are defined differently.

5.4. Secular Trends

A major impetus for deriving the Group Sunspot Numbers was to see if a homogeneous time series could be constructed. In particular, we sought to make the earlier observations consistent with the modern observations. In Section 4, we described our method of deriving these numbers and the errors associated with their derivation. It appears that the observations from 1653 to 1730 and from 1797 to the present are internally self-consistent to within 5%. Derived values between 1731 and 1796 are probably only self-consistent with modern observations to about the 15 to 20% level. Without the discovery of more observations, it will be difficult to reduce these errors.

The R_Z's are higher than the R_G's before 1882 at which time the method of constructing R_Z's was changed (Hossfield, 1997). In Figure 8, we summarize the differences between the R_Z's and R_G's by taking the ratio of the difference of the monthly means to the R_G's (i.e., $[R_Z - R_G]/R_G$) and smoothing them with an 11-year running mean. The largest difference occurs in 1808 when the R_Z's exceed the R_G's by 97%. For the interval 1803 to 1813 Wolf had very few observations. For 1803 he had five days and for 1804 he had four days. In Table III, we summarize the number of observations used as input for the R_Z's and R_G's for 1800 to 1813.

Table III

Number of days from all observers used by Wolf to construct the R_Z's from 1800 to 1813 compared to the number of observations available to derive the R_G's

Year	R_Z observations	R_G observations
1800	66	173
1801	38	235
1802	54	145
1803	5	150
1804	4	141
1805	75	100
1806	12	52
1807	31	266
1808	55	273
1809	41	305
1810	114	659
1811	67	820
1812	147	312
1813	174	462
Totals	883	4093

From the table it is evident we have more observations every year. More than 4000 observations are used to construct the R_G's while less than 1000 observations were available to Wolf. The paucity of observations caused Wolf to no longer give daily values before 1818. Because the R_G's are created from a larger input database, there is more opportunity to compare the observations to those made later. Thus, we are confident that the large differences between the R_Z's and R_G's shown in Figure 8 are caused by errors in the R_Z's. Furthermore, the R_Z's have an activity peak in 1805 compared to an activity peak in 1801 for the R_G's. The supposed long cycle of 17 years from 1788 to 1805 should actually be a cycle that extends from 1788 to 1801, or 13 years. There is a chance that the previous peak was in 1790 and not 1788 (see Appendix 2), but since 1790 was poorly observed, it cannot yet be definitively said this cycle lasted 11 years. There is another long cycle from 1801 to 1815 (14 years) which may be characteristic of the Sun when activity is low. The low activity cycles around 1800 are often called the Dalton Minimum.

Returning to Figure 8, we see that the R_Z's exceed the R_G's by about 30% for the interval 1750 to 1800. This difference exceeds by a factor of two our estimates of the systematic errors in the R_G's. The R_G's are similar to the numbers published by Wolf (1861) as shown in Table IV. In 1873 Wolf revised his numbers upwards using magnetic needle observations. The analysis in this paper supports his earlier derivation of solar activity instead of the later revisions which are now universally

Table IV

A comparison of yearly mean sunspot numbers for solar maxima between 1749 and 1850. Shown are the Group Sunspot Numbers, the Wolf Sunspot Numbers as published in 1861, and the Wolf Sunspot Numbers as published today. Note that the 1861 R_Z's are close to the R_G's. Both of these determinations relied on telescopic observations whereas the modern R_Z's for this era are a mixture of telescopic observations and magnetic needle observations. The question mark after the number 70.0 for the peak in 1805 reflects Wolf's uncertainty in his assigned value.

Year of solar max.	R_G	R_Z in 1861	R_Z today
1749	65.0	68.2 in 1750	80.9
1761	74.0	75.0	85.9
1769	102.4	85.7	106.1
1779	80.2	99.2 in 1778	154.4
1790	90.5	92.8 in 1787	132.0 in 1787
1801	49.9	70.0 (?) in 1805	47.5 in 1805
1816	31.3	45.5	45.8
1830	64.0	59.1	70.9
1837	109.9	111.0	138.3
1848	86.0	100.4	124.7

used. For the years 1749 to 1800 inclusive, the average R_G is 39.6, the 1861 R_Z average is 43.5, and the modern R_Z average is 53.7. The modern R_Z's exceed the 1861 R_Z's by 23%. This upward adjustment does not seem correct. Wolf's adjustment does produce the R_Z's such that the level of solar activity is roughly constant in each of the 50-year intervals from 1700 to the present and that may have been a motivation for his modification.

For the period 1700 to 1730, the R_Z's exceed the R_G's by a large percentage. We have thousands of observations for this period which Wolf did not have. Since no more than one group appeared on the solar disk before 1715, the cycle peaking in 1705 must be less than 10 and not the value of 58 reported by Wolf. The rise out of the Maunder Minimum took several cycles before it reached peaks comparable to more modern activity levels. The first cycle after the Maunder Minimum has a double peak in 1705 and 1707 as also reported by Baiada and Merighi (1982).

6. Conclusions

We have created a greatly improved record of solar activity via sunspot numbers that can be used by many disciplines (from solar physics to climatology). The objective of this study was the creation of self-consistent time series for solar activity with systematic and random errors estimated. This goal is met. The first step in the process was the collection of data. In this goal we succeeded in collecting many observations missed by Wolf and in improving the quality of the raw data for some observers. The number of observations available to construct the R_G's considerably exceeds the number used to construct the R_Z's.

By using multiple observers each day, the random errors in the daily means of the R_G's can be calculated. By using groups alone, versus groups and individual sunspots, it is possible to compare observers to one another and derive values for their observation constants, or k's, more easily. These k's were calculated by giving greater weights to the highest quality and most active observers and by minimizing the number of intermediate observers between the observer and the standard observer, RGO. Thus, the minimum path length, maximum number of minimum paths, and best comparisons are used to derive the k' values. This technique assures the maximum use of the data as opposed to selective and subjective approaches used by Wolf in deriving his observer constants. The technique allows us to place error bars on the k' values and we think gives us the best chance of producing a homogeneous time series.

The final data products consist of daily, monthly, and yearly means along with their one-standard-deviation uncertainties and the number of observations used to generate them. A supplemental bibliography with comments has also been generated so that the input data is traceable to the original sources, be they journals, books, or manuscripts. The raw data, the Group Sunspot Numbers, and supporting documentation are in 16 files at the National Geophysical Data Center in Boulder, Colorado. They may be accessed on the Worldwide Web at http://www.ngdc.noaa.gov/ or at ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_NUMBERS/GROUP_SUNSPOT_NUMBERS.

This generation and preliminary review of the Group Sunspot Numbers allow several conclusions to be made: (1) Solar activity before 1882 is lower than generally assumed and consequently solar activity in the last few decades is higher than it has been for several centuries. (2) There was a solar activity peak in 1801 and not 1805 so there is no long anomalous cycle of 17 years. The longest cycle observed now lasts no more than 15 years. (3) The R_Z's have many inhomogeneities in them arising from observer noise and this noise affects the daily, monthly, and yearly means. The Group Sunspot Numbers also have observer noise, but this is considerably less than the noise in the Wolf Sunspot Numbers.

There are no immediate plans to continuing working on the Group Sunspot Numbers or in keeping them current. If the observations by Chevallier, Soemmering (see Carrington, 1860), Fink (see Zinner, 1952), or other misplaced or missing observers become available, the database and processed results will be updated.

Acknowledgements

This work was supported by NASA Contract NASW-96024, NAG-5736, and NASA RTOP 344-12-53-18. We would like to thank the many librarians and scientists all over the world who have aided us in identifying and collecting observations. They include Ruth Freitag at the Library of Congress, Brenda Corbin and Gregory Shelton at the Naval Observatory Library, Dr Peter Hingley at the Royal Astronomical Society, Dr Adam Perkins at the Cambridge University Library, Dr Eigil Unstrup at the University of Copenhagen, Dr Kristian Peder Moesgaard at the University of Aarhus, and the State Library at St. Petersburg, Russia. We also would like to acknowledge helpful reviews by Charles Wolff and an anonymous reviewer.

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Appendix 1. List of Observers and Their Properties

Below are listed the 463 observers used in the Group Sunspot Number calculations. In the first column, an observer number is given. The next two columns give the first and last year that the observer recorded observations. The fourth column lists the number of observing days. The fifth column gives the correction factor to reduce these observations to the Royal Greenwich observatory scale. The next column gives the one standard deviation Uncertainty in the correction factor. The seventh column gives the number of standard or secondary standard observers used to calculate the correction factor. Zero means the observer is isolated and no contemporary observations overlap his or her observations. The last column on the right gives the observer name and primary location where the observations were made. More details are given in an extensive bibliography with comments (one of the files of NGCD called *biblio.txt*).

1	1610	1613	210	1.990	.000	1	HARRIOT, T., OXFORD
2	1611	1640	882	1.255	.112	0	SCHEINER, C., ROME
3	1612	1612	51	1.250	.000	1	GALILEO, G., ROME
4	1612	1612	37	1.077	.000	1	GALILEO/SAKURAI, ROME
5	1612	1612	20	1.255	.112	0	COLOGNA, S., MONREALE
6	1612	1613	104	2.305	.000	1	JUNGIUS, J., HAMBURG
7	1612	1612	29	3.125	.000	1	CIGOLI, L.C., ROME
8	1613	1614	51	1.255	.112	0	COLONNA, F., NAPLES
9	1615	1617	69	1.255	.112	0	TARDE, J., FARLAT
10	1616	1616	12	1.255	.112	0	SAXONIUS, P., NUREMBERG
11	1617	1618	541	1.255	.112	1	MARIUS, S., NUREMBERG
12	1618	1626	185	1.255	.112	0	MALAPERT, C., BELGIUM
13	1618	1661	491	1.255	.112	1	RICCIOLI, J.B., BONONIA
14	1621	1625	36	1.255	.112	0	SMOGULECZ, D., INGOLSTADT
15	1621	1629	4	1.255	.112	1	SCHICKARD, W., TUBINGA
16	1625	1625	1	1.255	.112	0	HORTENSIUS, M., LUGD. BATAV.
17	1626	1629	126	1.255	.112	0	MOGLING, D., DARMSTADT
18	1631	1645	709	1.255	.112	0	GASSENDI, P., PARIS
19	1631	1631	1	1.255	.112	1	QUIETANUS, J.R., GERMANY
20	1632	1632	366	1.255	.112	1	ZAHN, J., NUREMBERG
21	1633	1635	2	1.255	.112	1	OCTOUL, AVENIONE
22	1636	1747	0	1.255	.112	1	
23	1638	1638	6	1.255	.112	1	HORROX, J., LIVERPOOL
24	1638	1639	689	1.255	.112	0	CRABTREE, W., ENGLAND
25	1642	1684	4186	.988	.004	3	HEVELIUS, J., DANZIG
26	1642	1642	13	1.255	.112	1	RHEITA, K., BOHEMIA
27	1644	1644	1	1.255	.112	1	LINEMANNS, A., REGIOMONTUS
28	1648	1648	113	1.255	.112	1	UNKNOWN/KRAFT,1745
29	1652	1677	40	1.000	.044	6	PETITUS, P., PARIS
30	1652	1654	275	1.255	.112	1	UNKNOWN1/MAUNDER/JBAA
31	1653	1659	2352	1.255	.112	1	PICARD/KEILL, PARIS
32	1655	1655	13	1.255	.112	1	UNKNOWN2/MAUNDER/JBAA
33	1656	1695	466	1.034	.072	5	CASSINI, G.D., PARIS
34	1656	1656	13	1.255	.112	1	BOSE, J.A., LEIPZIG
35	1658	1672	273	1.255	.112	1	MARALDI, F., BONONIA
36	1659	1661	234	1.050	.032	2	MOUTON, G., LYON
37	1660	1660	14	1.000	.017	2	BOYLE, R., LONDON
38	1660	1682	3697	1.000	.043	8	PICARD, J., PARIS
39	1661	1671	3605	1.000	.017	2	FOGEL, M., HAMBURG
40	1662	1664	1096	1.255	.112	1	WEIGEL, E., JENA

41	1663	1695	6	1.255	.112	1	MEZZAVACCA, C., BONONIA
42	1663	1670	66	1.255	.112	1	MENGOLI, P., BONONIA
43	1666	1683	2	1.255	.112	1	HUYGENS, C., HAGUE
44	1666	1666	1	1.255	.112	1	PAYEN, A.-F., AVIGNON
45	1666	1666	1	1.255	.112	1	WILLOUGHBY, F., ENGLAND
46	1666	1667	730	1.255	.112	1	WEICKMANN, C., GERMANY
47	1667	1667	1	1.255	.112	1	KIRCHER, A., ROME
48	1668	1675	90	1.255	.112	1	FABRIUS, A., BONONIA
49	1671	1676	107	1.000	.079	4	MONTANARI, G., BONONIA
50	1671	1690	5400	1.000	.017	2	SIVERUS, H., HAMBURG
51	1671	1676	5	1.000	.051	4	HOOK, R., LONDON
52	1671	1671	11	1.000	.018	4	STETINI, LEIPZIG
53	1672	1673	130	1.255	.112	1	RICHER, CAYENNE
54	1672	1676	20	1.358	.002	3	LALANDE, MEMOIRES, PARIS
55	1673	1673	1	1.255	.112	1	MANZIUS, D., BONONIA
56	1674	1674	19	1.255	.112	1	PICARD, J., MONTPELLIER
57	1674	1674	20	1.255	.112	1	CALCINA, J.C., BONONIA
58	1675	1696	406	1.000	.014	4	GULIELMINI, J.F., BONONIA
59	1676	1714	1500	1.009	.259	10	FLAMSTEED, J., CAMBRIDGE
60	1676	1676	9	1.000	.052	4	HALLEY, E., LONDON
61	1676	1676	2	.753	.116	4	MOORE, J., LONDON (RS ARCHIVES)
62	1676	1676	1	1.255	.112	1	HAYNES, CAMBRIDGE
63	1677	1702	2325	.993	.108	3	EIMMART, G.C., NUREMBERG
64	1677	1677	7	1.000	.037	2	HARTSOEKER, N., THE HAGUE
65	1678	1678	1	1.000	.037	2	MACULA IN SOLE, 1678
66	1678	1710	481	1.188	.064	4	KIRCH, G., BERLIN
67	1678	1684	9	1.086	.258	3	ETTMULLER, M.E., WITTENBERG
68	1680	1680	23	1.255	.112	1	PICARD, J., BAYONNE
69	1680	1687	3	1.000	.248	2	IHLE, J.A., BERLIN
70	1681	1681	20	1.255	.112	1	PICARD, J., ENGLAND
71	1681	1681	60	1.255	.112	1	VARIN, M.M., CAPE VERDE VOYAGE
72	1681	1681	1	1.255	.112	1	DESHAYES, M., ROUEN
73	1682	1718	7170	.996	.012	2	LA HIRE, PH., PARIS
74	1684	1684	2	1.002	.247	2	CASWELL (R.S.), LONDON
75	1684	1684	18	1.049	.242	3	CLAUSEN, F., KILONI
76	1684	1718	952	.990	.024	5	WURZELBAUR, J.P., NUREMBERG
77	1686	1686	9	1.255	.112	1	JESUITS, CHINA
78	1687	1689	2	1.255	.112	1	SCHULTZ, D.G., NUREMBERG
79	1688	1736	497	.979	.010	4	MARALDI, M., BONONIA
80	1688	1693	5	1.255	.112	1	ARNOLD, C., BERLIN
81	1689	1689	339	1.255	.112	1	DECHALES, M., LUGDUNI
82	1690	1723	4	1.255	.112	1	MENTZER, B., HAMBURG
83	1694	1703	2	1.255	.112	1	BRATTLE, T., BOSTON
84	1695	1696	41	1.255	.112	1	UCCELLI, I., BONONIA
85	1695	1699	2	1.255	.112	1	MOEREN, J.T., NUREMBERG
86	1695	1707	1983	.988	.006	3	AGERHOLM, C., COPENHAGEN
87	1696	1702	1103	1.255	.112	1	STANCARIUS, V.F., BONONIA
88	1697	1697	21	1.255	.112	1	CASSINI, G.D., FLANDERS
89	1698	1698	9	1.255	.112	1	CASSINI, G.D., LONDON
90	1699	1699	1	1.255	.112	1	MEYER, J., REGENSBURG
91	1700	1709	214	1.097	.253	2	CASSINI, J., PARIS
92	1701	1705	19	.989	.021	3	JARTOUX, R.P., PEKING
93	1702	1738	714	1.560	.022	2	MANFREDI, E., BONONIA
94	1703	1704	141	1.149	.242	4	EIMMART, M-C., NUREMBERG
95	1703	1727	130	.808	.045	3	BLANCHINI, F., VERONA
96	1703	1715	1613	1.681	.282	2	DERHAM, W., UPMINSTER
97	1703	1703	22	1.080	.217	4	HOFFMANN, J.H., BERLIN
98	1703	1713	80	1.070	.141	5	GRAY, S., CANTERBURY

99	1703	1703	17	1.255	.112	1	SHARP, A., HORTON
100	1703	1704	12	1.074	.116	5	ROMER, O., COPENHAGEN
101	1703	1704	72	.898	.113	5	STANNYAN, ENGLAND
102	1704	1704	1	1.013	.064	4	SALVAGO, M., GENNES
103	1704	1704	1	1.013	.064	4	DE LA VAL, P., MARSEILLE
104	1704	1726	423	1.107	.000	3	PLANTADE, J., MONTPELLIER
105	1704	1704	1	1.013	.064	4	DE CLAPIER, M., MONTPELLIER
106	1704	1704	1	1.013	.064	4	FULCHIRON, P., LYON
107	1704	1704	1	1.013	.064	4	THYOLI, LYON
108	1705	1709	87	1.048	.104	7	LALANDE, HISTORIE, PARIS
109	1705	1709	80	1.000	.001	6	MULLER, J.H., NUREMBERG
110	1706	1721	5	1.220	.000	1	SCHEUCHZER, J.J., ZURICH
111	1706	1706	1	1.255	.112	1	TORRE, F., ARLES
112	1707	1707	2	.973	.061	3	HERTEL, C.T., BERLIN
113	1707	1707	2	.983	.019	4	STURM, L.C., BERLIN
114	1708	1709	255	1.026	.025	6	WIEDENBURG, J.B., HELMSTADT
115	1709	1722	59	.922	.116	5	FEUILLEE, L.E., PARIS
116	1709	1709	2	.834	.190	4	WOLF, C., MAGDEBURG
117	1709	1709	182	1.255	.112	1	UNKNOWN3/MAUNDER/JBAA
118	1710	1713	204	1.255	.112	1	PARISIUS, J.C., BONONIA
119	1713	1715	58	1.381	.270	3	KIRCH, M.M., BERLIN
120	1713	1735	39	.900	.072	4	DE L'ISLE, J.N., PARIS
121	1713	1713	5	1.041	.177	5	UNKNOWN/LALANDE
122	1715	1727	3	.802	.051	2	POLENI, J., PADUA
123	1715	1715	1	1.255	.112	1	GESU, P.A.B., PARMA
124	1715	1715	1	1.255	.112	1	FONTANA, P.B.G., MODENA
125	1716	1736	394	1.071	.026	3	KIRCH, C., BERLIN
126	1716	1718	3	2.380	.700	4	MULLER, J.H., ALTORFII
127	1716	1726	299	.557	.335	3	ROST, J.L., NUREMBERG
128	1718	1719	121	1.051	.020	2	LA HIRE, G., PARIS
129	1718	1746	7	1.255	.112	1	HALLERSTEIN, A., PEKING
130	1718	1718	1	1.004	.022	2	WAGNER, J.W., BERLIN
131	1719	1727	524	1.256	.051	2	ALISCHER, J.L., JAUER
132	1719	1720	45	.991	.002	2	MULLER, J.C., PRAGUE
133	1720	1736	14	1.455	.069	3	SCHUTZ, J.G., BERLIN
134	1720	1720	5	1.790	.000	1	LAVAL, A.F., PARIS
135	1720	1739	32	.931	.049	4	WEIDLER, J.F., WITTENBERG
136	1721	1721	1	1.220	.000	1	TRAUTMANN, G., LOBAU
137	1722	1739	4	1.032	.227	2	BRADLEY, J., GREENWICH
138	1722	1722	1	1.078	.038	2	ROBIE, T., BOSTON
139	1724	1724	1	.802	.051	2	FALK, J., MUNICH
140	1724	1724	1	.802	.051	2	GRAMMATICI, N., INGOLSTADT
141	1724	1724	1	.802	.051	2	BANDERIO, J.B., ITALY
142	1724	1724	1	.802	.051	2	PARMA, J., ITALY
143	1725	1725	9	1.255	.112	1	GAUBIL, A., CHINA
144	1725	1725	1	1.000	.055	2	HAUSEN, C.A., LEIPZIG
145	1725	1725	11	1.078	.038	2	LIEFMANN, D.F., BUDISSIN
146	1726	1726	1	.415	.030	2	GODIN, L., PARIS
147	1726	1726	1	1.526	.105	2	SOUCIET, E., LYON
148	1727	1727	16	1.255	.112	1	WALTHER, J.M., WITTENBERG
149	1727	1750	7	1.018	.059	2	CASSINI DE THURY, PARIS
150	1727	1727	1	.399	.027	2	CARBONE, J.B., ROME
151	1729	1733	47	1.255	.112	0	BEYER, J., HAMBURG
152	1729	1729	14	1.255	.112	1	KRAFT, G.W., ST. PETERSBURG
153	1730	1733	367	1.255	.112	0	ADELBURNER, M., NUREMBERG
154	1730	1730	2	1.255	.112	1	WASSE, J., NORTHAMPTONSHIRE
155	1733	1782	3	.979	.039	3	LE MONNIER, P.C., PARIS
156	1734	1734	1	1.255	.112	1	ECLIPSE OBSERVERS, ROME

157	1735	1735	1	1.255	.112	1	BARATIER, HALLE
158	1735	1735	5	1.255	.112	1	RUCKKEHR, HALLE
159	1737	1737	1	.708	.048	2	ANONYMOUS, BONONIA
160	1737	1743	2	1.000	.037	2	GRAHAM, G., LONDON
161	1739	1751	116	.789	.118	4	HAGEN, F., BERLIN
162	1739	1739	2	1.255	.112	1	HUXHAM, J., ENGLAND
163	1739	1739	1	1.255	.112	1	SHAW, ALEXANDRIA
164	1739	1742	66	1.255	.112	1	MUSANO, M., VENICE
165	1739	1753	5	.440	.033	3	ZANOTTI, E., BONONIA
166	1739	1742	6	1.255	.112	1	WINTHROP, J., CAMBRIDGE, MA
167	1743	1743	1	1.255	.112	1	GERSTEN, C.L., GIESSEN
168	1743	1748	2	.978	.075	4	BOSE, G.M., WITTENBERG
169	1748	1773	7	1.951	1.432	4	DARQUIER, A., PARIS
170	1748	1778	2	1.747	.477	4	ULLOA, A., MADRID
171	1748	1769	2	1.142	.131	5	BEVIS, J., OXFORD
172	1749	1799	1142	2.000	.390	4	STAUDACHER, J.C., NUREMBERG
173	1750	1799	11	.923	.368	4	MESSIER, PARIS
174	1752	1798	105	.903	.231	5	LALANDE, J., PARIS
175	1753	1753	1	7.860	.112	1	PINGRE, A.G., PARIS
176	1753	1756	2	1.255	.112	0	MAYER, T., GOTTINGEN
177	1754	1760	899	1.255	.112	0	ZUCCONI, L., VENICE
178	1754	1758	492	1.255	.112	0	SCHUBERT, J.C., DANZIG
179	1758	1758	1	1.255	.112	1	BRAUNIO, J.A., ST. PETERSBURG
180	1761	1776	1532	1.565	.000	3	HORREBOW, C., COPENHAGEN
181	1761	1764	2	1.000	.043	2	ZURCH (JOURNAL NAME)
182	1762	1762	7	1.255	.112	0	POCZOBUT, L.P., MARSEILLES
183	1762	1762	1	1.255	.112	0	HIRST, W., CALCUTTA
184	1764	1764	5	1.255	.112	0	HOFMANN, C., DRESDEN
185	1764	1766	3	1.255	.112	1	WARSCHAUER
186	1764	1764	1	1.255	.112	1	ROGALINSKY, P., ST. PETERSBURG
187	1767	1776	1261	2.012	.009	3	HORREBOW/WOLF, COPENHAGEN
188	1768	1769	2	.901	.369	3	FERGUSON, J., EDINBURGH
189	1769	1769	1	.910	.290	4	HORNSBY, T., OXFORD
190	1769	1769	1	.881	.333	4	WOLLASTON, F., LONDON
191	1769	1769	1	.923	.157	4	BRYCE, ENGLAND
192	1769	1769	6	1.703	.324	4	RUMOVSKI, S., KOLA
193	1769	1769	1	.923	.157	4	BAILLY, J-S., PARIS
194	1769	1769	1	.923	.157	4	ACKERMANN, J.F, KILIA
195	1769	1769	1	1.111	.099	4	FELBIGER, SAGAN
196	1769	1769	1	.853	.102	4	WRIGHT, CANADA
197	1770	1774	410	1.337	.001	2	HORREBOW - VERSION 2
198	1770	1770	2	1.091	.116	3	ROSSLER, G., TUBINGEN
199	1771	1781	4	1.040	.068	4	WOLF, DIRSCHAU
200	1772	1772	1	1.255	.112	0	GOLDHOVER, MUNICH
201	1773	1777	87	1.393	.439	2	MALLET, J.A., BERLIN
202	1774	1822	67	.993	.032	2	BODE, J.E., BERLIN
203	1776	1777	196	.893	.361	4	LIEVOG, E., COPENHAGEN
204	1776	1776	17	.985	.041	4	FIXLMILLNER, P., STYRIA
205	1777	1802	43	.775	.116	2	BUGGE, T., COPENHAGEN
206	1777	1777	14	2.291	.000	1	BOSCOVICH, R.J., VENICE
207	1777	1777	3	1.255	.112	1	REGGIO, MILAN
208	1778	1778	97	1.040	.286	3	ORIANI, B., MILAN
209	1778	1778	1	1.039	.411	3	SCHULZE, J.K., BERLIN
210	1778	1778	1	1.072	.078	3	MAYER, T., MANNHEIM
211	1778	1778	1	1.035	.367	3	KRATZENSTEIN, COPENHAGEN
212	1778	1778	1	1.030	.259	3	HELFENZREIDER, J.E., INGOLSTADT
213	1779	1781	3	1.255	.112	1	ZENO, P., PRAGUE
214	1780	1780	1	1.255	.112	0	WILLIAMS, S., PENOBSCOT BAY

215	1780	1780	1	1.255	.112	0	BROWN, J., PROVIDENCE, RI
216	1780	1780	1	1.255	.112	0	PAYSON, P., CAMBRIDGE, MA
217	1781	1799	15	5.111	.000	1	STRNADT, PRAGUE
218	1781	1820	398	1.002	.009	2	HEINRICH, P., MUNICH
219	1782	1782	1	1.255	.112	1	HENNERT, J.F., UTRECHT
220	1785	1785	1	1.255	.112	0	KONIG, K.J., MANNHEIM
221	1785	1785	1	1.255	.112	0	BEIGEL, G.W.S., DRESDEN
222	1785	1785	1	1.255	.112	0	LIPPOLD, G.H.E., WIEN
223	1786	1786	1	.973	.000	1	PIGOTT, E., BOOTHAM
224	1786	1793	11	1.255	.112	1	SCHROTER, J.H., LILIENTHAL
225	1787	1787	1	1.718	.000	1	METZBURG, G.I., WIEN
226	1787	1787	1	1.718	.000	1	TOALDO, J., PATVINA
227	1788	1830	2068	2.077	.690	4	FLAUGERGUES, H., VIVIERS
228	1788	1788	1	1.255	.112	0	TREISNECKER, F.V.P., WIEN
229	1788	1788	1	1.255	.112	0	ZOLLINGER, INNSBRUCK
230	1791	1806	3	.808	.000	1	FEER, ZURICH
231	1791	1791	1	1.617	.000	1	SANDT, RIGA
232	1791	1791	1	4.849	.000	1	BEITLER, MITAU
233	1791	1791	1	.970	.000	1	CASSINI, J.D., THURY
234	1793	1803	5	2.564	.015	2	HUBER, J.J., BASEL
235	1794	1811	635	1.255	.112	0	ENDE, F.A., CELLE
236	1794	1818	384	1.393	.076	2	HERSCHEL, W., LONDON
237	1796	1797	130	1.255	.112	0	FLAUGERGUES, H. (C.DE.T.)
238	1797	1797	3	1.255	.112	1	GEMEINER, A.T., REGENSBURG
239	1797	1797	1	1.255	.112	1	REINCKE, HAMBURG
240	1797	1797	2	1.255	.112	0	HAMILTON, J., ARMAGH OBS., IRELAND
241	1798	1798	3	1.255	.112	1	DANGOS, MALTA
242	1798	1812	454	.960	.009	2	FRITSCH, J.H., GERMANY
243	1798	1798	5	.951	.020	2	KOHLER, J.G., GERMANY
244	1800	1807	291	1.255	.112	1	FLAUGERGUES, H. (C.DE T.)
245	1800	1827	519	1.136	.219	4	LINDENER, B.A., GLATZ
246	1802	1824	789	1.280	.014	2	DERFFLINGER, T., KREMSMUNSTER
247	1803	1803	1	1.255	.112	1	BEDE, WIEN
248	1803	1803	1	1.255	.112	0	CHIMINELLO, PADUA
249	1804	1804	1	.749	.022	2	SCHUBERT, F.T., ST. PETERSBURG
250	1804	1844	115	.871	.047	2	PRANTNER, S.M.J., WILTEN
251	1804	1804	1	.624	.018	2	CASSELLA, MADRID
252	1806	1810	284	2.287	.000	1	BUGGE, M., COPENHAGEN
253	1811	1844	405	1.255	.112	1	GRUITHUISEN, B., MUNICH
254	1813	1835	1048	1.255	.112	1	STARK, AUGSBURG, ZERO DAYS
255	1813	1836	2569	1.165	.002	3	STARK, J.M., AUGSBURG
256	1814	1814	17	.971	.144	3	GAUSS, H. FR., GOTTINGEN
257	1815	1816	6	1.724	.773	5	EYNARD, ROLLE
258	1816	1836	858	1.188	.181	3	TEVEL, C., MIDDELBURG
259	1816	1829	21	1.232	.077	4	ESMARK, KONGSBERG
260	1816	1818	83	.969	.022	4	WATTS, CAPE DIAMOND, QUEBEC
261	1817	1817	5	1.153	.059	3	BIANCHI, G., MODENA
262	1819	1823	977	1.063	.054	11	ADAMS, C.H., EDMONTON
263	1819	1833	1477	1.005	.036	7	PASTORFF, J.W., DROSSEN
264	1819	1833	1767	.548	.020	7	PASTORFF/WOLF, DROSSEN
265	1819	1819	3	3.051	.918	7	HALLASCHKA, F.I.C., PRAGUE
266	1820	1820	1	1.255	.112	1	NICOLAI, F., MANNHEIM
267	1820	1820	1	1.255	.112	1	ZACH, F.X., GOTHA
268	1820	1820	1	1.255	.112	1	LUTHMER, HANNOVER
269	1820	1847	4	1.029	.080	3	GERLING, C.L., MARBURG
270	1820	1820	1	1.255	.112	1	VAN SWINDEN, AMSTERDAM
271	1821	1821	1	.451	.000	1	STRUVE, F.G.W., DORPAT
272	1821	1822	24	1.138	.097	5	ARGELANDER, BONN

273	1822	1830	923	1.592	.529	6	ARAGO, F.D., PARIS
274	1822	1837	122	1.203	.017	5	HERSCHEL, J., LONDON
275	1823	1823	9	1.073	.098	4	LORENZ, WITTENBURG
276	1823	1824	16	1.064	.064	6	BIELA, J., PRAGUE
277	1825	1830	364	1.280	.089	6	SCHWARZENBRUNNER, KREMS.
278	1825	1826	183	1.121	.091	6	VON BOTH, G., BRESLAU
279	1826	1867	11945	1.208	.058	9	SCHWABE, H., DESSAU
280	1826	1837	1207	1.365	.042	7	HUSSEY, T.J., ENGLAND
281	1826	1826	1	1.255	.112	1	BEAUFOY, G., BUSHEY HEATH
282	1831	1832	200	1.528	.112	3	LAWSON, H., HEREFORD
283	1832	1832	39	1.027	.139	2	RUPRECHT, H., ZIEGENHAIN
284	1832	1832	17	1.165	.072	3	BOGUSLAWSKI, P.H.L., BRESLAU
285	1833	1836	101	1.254	.120	2	BOHM, J.G., WIEN
286	1833	1833	1	1.125	.058	2	SMYTH, BEDFORD
287	1835	1836	158	1.692	.314	3	KUNITOMO, OMI
288	1837	1837	2	1.255	.112	1	HAILE, A.B., YALE
289	1840	1840	1	.966	.022	2	GALLE, J.G., BERLIN
290	1840	1841	13	1.000	.044	2	PETERSEN, A.C., ALTONA
291	1840	1840	1	.825	.080	2	LOHSE, POTSDAM
292	1841	1883	6970	1.135	.003	2	SCHMIDT, ATHENS
293	1843	1843	1	1.255	.112	1	CALDECOTT, J., MAHE
294	1844	1870	1308	.976	.060	8	PETERS, C.H.F., CLINTON, NY
295	1847	1866	5538	1.249	.110	8	SHEA, C., ENGLAND
296	1847	1849	137	.750	.070	3	BOND, W.C., HARVARD
297	1847	1847	1	1.190	.047	3	SCHWEIZER, G., MOSCOW
298	1848	1893	10026	1.117	.090	4	WOLF, R., ZURICH
299	1850	1865	168	.937	.057	4	GREISBACH, T.J., ENGLAND
300	1850	1850	42	.758	.020	3	SESTINI, GEORGETOWN
301	1850	1850	2	1.066	.125	3	FLEISCHHAUER, J., LANGENSALZA
302	1850	1850	6	.925	.040	3	VON JAHN, LEIPZIG
303	1851	1860	124	1.209	.029	6	AIRY, G.B., LONDON
304	1851	1851	13	.991	.015	3	POGSON, N., LONDON
305	1852	1854	15	1.198	.094	4	TOMASCHEK, WIEN
306	1852	1855	19	.992	.146	4	BORCK, CASSEL
307	1853	1860	1215	1.034	.117	6	CARRINGTON, LONDON
308	1857	1858	16	1.433	.192	3	FLAGSTAFF OBS., MELBOURNE
309	1857	1857	181	1.003	.003	3	ELLNER, BAMBERG
310	1857	1872	99	1.409	.197	10	HEIS, MUNSTER
311	1859	1883	6983	.978	.068	4	WEBER, PECKELOH
312	1859	1892	766	1.217	.111	3	HOWLETT, F., ENGLAND
313	1859	1859	7	1.199	.201	5	BAXENDALL, J., MANCHESTER
314	1860	1862	475	1.112	.194	6	COAST SURVEY, WASHINGTON
315	1860	1863	275	1.855	.380	7	FRANZENAU, F., WIEN
316	1861	1865	585	1.002	.020	7	JENZER, BERN
317	1861	1862	138	.993	.012	4	KLEIN, KOLN
318	1861	1893	6283	1.094	.074	3	SPOERER, G., ANCLAM
319	1862	1862	94	1.002	.053	4	BORNITZ, H., LICHTENBERG, BERLIN
320	1863	1864	41	1.097	.078	4	WALDNER, ZURICH
321	1864	1871	912	1.008	.060	13	MEYER, ZURICH
322	1864	1866	451	1.004	.060	5	DE LA RUE, LONDON
323	1866	1879	478	.985	.011	3	FERRARI, ROME
324	1867	1881	2611	1.111	.009	4	LEPPIG, LEIPZIG
325	1867	1890	1623	1.010	.093	3	DAWSON, W.M., SPICELAND, IND
326	1870	1872	10	.985	.038	9	HARVARD COLLEGE OBS., MA
327	1870	1879	2059	1.027	.019	2	BERNAERTS, G.L., ENGLAND
328	1871	1900	7584	1.059	.066	2	TACCHINI, ROME
329	1871	1877	1530	.969	.008	2	SECCHI, ROME
330	1872	1875	308	1.048	.018	2	BILLWILLER, ZURICH

331	1872	1874	282	1.211	.068	2	SAWYER, E.F., CAMBRIDGEPORT
332	1874	1976	37472	1.000	.001	2	ROYAL GREENWICH OBSERVATORY
333	1874	1893	3598	1.227	.146	2	MONCALIERI
334	1874	1875	107	1.170	.064	2	MAIN, RADCLIFFE OBS., OXFORD
335	1876	1879	997	.838	.008	2	BILLWILLER AND WOLFER, ZURICH
336	1876	1882	1940	.796	.049	2	AGUILAR, MADRID
337	1877	1886	2383	1.021	.063	2	MONTHLY WEATHER REVIEW
338	1880	1928	12536	1.094	.016	2	WOLFER, ZURICH
339	1880	1892	3709	.896	.026	2	RICCO, PALERMO
340	1882	1882	88	1.007	.052	2	MIETHE, POTSDAM
341	1882	1910	6161	1.148	.162	2	WINKLER, JENA
342	1882	1887	1164	1.014	.031	2	JANESCH, LAIBACH
343	1883	1896	3221	.997	.000	2	MERINO, MADRID
344	1884	1886	965	1.429	.000	1	KOKIDES, ATHENS
345	1885	1905	3531	1.604	.000	1	KONKOLY, OGYALLA
346	1886	1886	162	1.392	.000	1	VOGEL, POTSDAM
347	1886	1935	4534	1.329	.000	1	STONYHURST COLLEGE OBS.
348	1887	1887	52	2.000	.000	1	WILSING, POTSDAM
349	1888	1892	1359	1.180	.000	1	SCHMOLL, PARIS
350	1888	1899	2063	1.274	.000	1	HAVERFORD COLLEGE OBS., PA
351	1888	1890	326	1.178	.000	1	YENDELL, P.S., BOSTON
352	1889	1921	10860	1.440	.000	1	QUIMBY, PHILADELPHIA
353	1889	1892	523	1.270	.000	1	CARLETON COLLEGE OBSERVATORY
354	1889	1890	262	1.055	.000	1	FROST, E.B., DARTMOUTH
355	1890	1891	258	1.056	.000	1	SMITH OBSERVATORY
356	1890	1890	67	1.040	.000	1	HADDEN, D.E., ALTA, IOWA
357	1890	1890	9	1.273	.000	1	FURNISS, C., VASSAR
358	1890	1925	2799	1.603	.000	1	MOUNT HOLYOKE COLLEGE
359	1891	1895	1173	1.265	.000	1	SCHREIBER, KALOCSA
360	1891	1891	282	.958	.000	1	ZONA, PALERMO
361	1892	1909	3619	1.110	.000	1	SCHWAB, KREMSMUNSTER
362	1893	1918	7620	1.248	.000	1	CATANIA
363	1893	1893	126	1.213	.000	1	LEWITZKY, CHARKOW
364	1894	1895	186	1.152	.000	1	FAUQUEZ, ZURICH
365	1894	1894	139	1.822	.000	1	WONASZEK, KIS-KARTAL
366	1894	1910	1883	1.308	.000	1	SYKORA, CHARKOW
367	1895	1896	233	1.136	.000	1	HOFFLER, ZURICH
368	1895	1907	1279	1.351	.000	1	LEWITZKY, JURJEW
369	1895	1901	632	1.062	.000	1	MAIER, SCHAUFLING
370	1896	1935	9492	1.210	.000	1	BROGER, ZURICH
371	1896	1900	154	1.236	.000	1	TILLSON, L.O., BOSTON U., MA
372	1896	1897	160	1.299	.000	1	MORGAN, H.R., LEANDER MCCORMICK OBS.
373	1897	1901	254	1.219	.000	1	OLIVER, A.I., BOSTON U., MA
374	1897	1898	113	1.423	.000	1	LYON, J.A., LEANDER MCCORMICK OBS.
375	1898	1900	149	1.205	.000	1	JASTREMSKY, B., CHARKOW
376	1898	1919	2881	1.390	.000	1	WOINOFF, MOSCOW
377	1898	1900	135	1.169	.000	1	MIRKOWITSCH, JAROSLAW
378	1898	1903	530	1.387	.000	1	FREYBERG, ST. PETERSBURG
379	1898	1901	649	.855	.000	1	KAULBARS, ST. PETERSBURG
380	1899	1918	1965	1.181	.000	1	KLEINER, ZOBTEN
381	1900	1900	102	1.264	.000	1	KITSCHIGIN, SPITZBERGEN
382	1900	1908	1017	1.495	.000	1	SUBBOTIN, ST. PETERSBURG
383	1901	1908	603	1.072	.000	1	GORJATSCHY, MOSCOW
384	1901	1903	202	1.220	.000	1	LARIONOFF, MOHILEW
385	1901	1902	179	1.208	.000	1	STRUVE, CHARKOW
386	1902	1925	6340	1.251	.000	1	GUILLAUME, LYON
387	1902	1910	1057	1.471	.000	1	SCHATKOW, KOLA
388	1902	1910	1715	1.254	.000	1	MESSERSCHMITT, MUNCHEN

389	1903	1925	2760	1.815	.000	1	STEMPELL, HANNOVER
390	1903	1906	672	1.720	.000	1	AMHERST COLLEGE OBSERVATORY
391	1903	1906	359	1.510	.000	1	BOSTON UNIVERSITY OBS.
392	1904	1909	58	1.301	.000	1	MOROSOFF, MOSCOW
393	1904	1905	230	1.553	.000	1	OSSIPOFF, TASCHKENT
394	1905	1912	455	1.392	.000	1	WASNETZOFF, MOSCOW
395	1906	1906	144	1.735	.000	1	BELAR, LAIBACH
396	1906	1916	1748	1.395	.000	1	HRASE, PRAGUE
397	1906	1906	127	1.323	.000	1	BRUNNER, CHUR
398	1906	1916	1674	2.044	.000	1	BODOCS, OGYALLA
399	1907	1907	114	1.295	.000	1	GINORI, FLORENCE
400	1907	1908	113	1.337	.000	1	SORMANO, TURIN
401	1907	1919	2748	2.031	.000	1	BEMMELEN, BATAVIA
402	1907	1907	155	1.198	.000	1	SYKORA, TASCHKENT
403	1908	1909	377	1.122	.000	1	BISKE, ZURICH
404	1908	1908	51	1.727	.000	1	SCHONBERG, JURJEW
405	1908	1914	1190	1.342	.000	1	LUCCHINI, FLORENCE
406	1908	1910	943	1.004	.000	1	GUERRIERI, CAPODIMONTE
407	1909	1925	1586	1.613	.000	1	BRAAK, BATAVIA
408	1909	1913	260	.741	.000	1	STEFKO, LEYSIN
409	1910	1914	654	1.419	.000	1	SCHWARZ, KREMSMUNSTER
410	1910	1916	297	2.642	.000	1	LISSAK, CHARLOTTENBURG
411	1911	1913	771	1.089	.000	1	KAVAN, PRAGUE
412	1911	1925	4744	2.062	.000	1	MOYE, MONTPELLIER
413	1913	1914	143	1.509	.000	1	MILORADOWITSCH, PULKOWO
414	1914	1925	1898	1.177	.000	1	BUTTLAR, SIMSDORF
415	1915	1915	225	2.236	.000	1	SCHMID, ST. GALLEN
416	1915	1918	815	1.910	.000	1	HEIMEN, FELDE
417	1916	1918	411	1.463	.000	1	BUGOSLAWSKY, MOSCOW
418	1917	1985	10890	2.257	.000	1	MT. WILSON, CENTER OF DISK
419	1917	1917	33	1.739	.000	1	REED, KENNEBUNK, MAINE
420	1917	1917	181	1.885	.000	1	TASS, OGYALLA
421	1918	1918	198	1.554	.000	1	VOSS, ALTONA
422	1918	1918	112	1.871	.000	1	MALSCH, KARLSRUHE
423	1918	1918	35	1.667	.000	1	SEIDEL, RHEINLAND
424	1918	1918	28	3.670	.000	1	WEGNER, DANZIG
425	1918	1918	103	2.243	.000	1	KLANNICK, GOTHA
426	1920	1921	455	1.889	.000	1	BATAVIA
427	1923	1958	11668	.983	.000	1	MT. WILSON, FULL DISK
428	1926	1944	4901	1.104	.000	1	BRUNNER, ZURICH
429	1928	1937	2722	1.173	.000	1	BUSER, AROSA
430	1928	1929	450	1.346	.000	1	N.A.O., JAPAN, K=0.85
431	1929	1944	3262	1.087	.000	1	BRUNNER, W., ZURICH
432	1930	1930	244	1.238	.000	1	N.A.O., JAPAN, K=0.75
433	1931	1934	921	1.154	.000	1	N.A.O., JAPAN, K=0.65
434	1935	1948	1293	1.137	.000	1	N.A.O., JAPAN, K=0.70
435	1935	1972	8995	1.323	.000	1	MADRID OBSERVATORY, MADRID
436	1936	1947	1615	.994	.000	1	WALDMEIER, ZURICH
437	1936	1936	207	1.019	.000	1	N.A.O., JAPAN, K=0.55
438	1936	1954	3357	1.078	.000	1	PROTITCH, M., BELGRADE
439	1937	1944	2059	1.047	.000	1	N.A.O., JAPAN, K=0.60
440	1941	1944	1298	1.122	.000	1	RAPP, LOCARNO-MONTI
441	1941	1956	3841	1.298	.000	1	VALENCIA OBS., VALENCIA
442	1942	1944	308	1.207	.000	1	WALDMEIER, AROSA
443	1946	1946	159	1.003	.000	1	DJURKOVIC, P.M., BELGRADE
444	1947	1949	331	1.100	.000	1	OSKANJAN, V., BELGRADE
445	1947	1984	7665	1.151	.000	1	KOYAMA, H., TOKYO
446	1948	1956	3211	1.080	.000	1	U.S. NAVAL OBSERVATORY

447	1949	1993	12243	1.083	.000	1	NATIONAL ASTRON. OBS., JAPAN
448	1949	1950	158	1.134	.000	1	SIMIC, M., BELGRADE
449	1949	1954	691	1.153	.000	1	DIZER, M., KANDILLI OBS.
450	1949	1950	191	1.482	.000	1	KORT, W., ST. MARIABURG
451	1952	1965	1274	1.113	.000	1	SAN MIGUEL OBS., ARGENTINA
452	1955	1968	1931	1.271	.000	1	OZGUC, A., KANDILLI OBS.
453	1956	1975	6532	1.230	.000	1	LEE OBSERVATORY, BIERUT
454	1958	1989	7104	1.394	.000	1	ROME OBSERVATORY
455	1962	1991	8606	1.059	.000	1	MT. WILSON NETWORK
456	1964	1993	5765	1.655	.000	1	TAIPEI
457	1967	1992	5120	1.287	.000	1	LUNPING OBSERVATORY, TAIWAN
458	1974	1975	455	1.213	.000	1	DOGAN, N., ANKARA
459	1977	1995	6922	.989	.026	5	SPACE ENVIRONMENT LABORATORY
460	1977	1977	365	.996	.015	5	DEBRECHEN HELIOPHYSICAL OBS.
461	1978	1987	3288	1.142	.052	5	CATANIA OBSERVATORY
462	1981	1991	3572	1.004	.052	5	AIR FORCE NETWORK
463	1992	1995	1002	1.298	.134	2	BRITISH ASTRON. ASSOC.

Appendix 2. Yearly Mean Group and Wolf Sunspot Numbers with Number of Observations (D) and Uncertainty (sig) for the R_G's

Year	D	R_G	sig	R_Z	Year	D	R_G	sig	R_Z
1600					1650	365	0.0	0.0	
1601					1651	365	0.0	0.0	
1602					1652	63	2.0	0.2	
1603					1653	343	0.8	0.0	
1604					1654	365	0.7	0.0	
1605					1655	365	0.5	0.0	
1606					1656	366	0.5	0.0	
1607					1657	365	0.2	0.0	
1608					1658	365	0.0	0.0	
1609					1659	365	0.0	0.0	
1610	1	72.0	4.6		1660	366	2.0	0.1	
1611	59	54.7	5.9		1661	365	0.8	0.0	
1612	360	92.1	2.7		1662	365	0.0	0.0	
1613	136	92.3	7.8		1663	365	0.0	0.0	
1614	1	121.0	15.5		1664	366	0.0	0.0	
1615	13	30.1	3.7		1665	365	0.0	0.0	
1616	67	21.6	2.3		1666	365	0.0	0.0	
1617	219	0.8	0.0		1667	365	0.0	0.0	
1618	365	1.3	0.0		1668	366	0.0	0.0	
1619	21	15.0	1.8		1669	365	0.0	0.0	
1620	45	15.0	1.7		1670	365	0.0	0.0	
1621	52	15.0	1.7		1671	330	1.0	0.0	
1622	34	15.0	1.8		1672	366	0.4	0.0	
1623	11	15.0	1.9		1673	356	0.0	0.0	
1624	61	11.1	1.2		1674	215	0.2	0.0	
1625	365	42.4	1.2		1675	365	0.0	0.0	
1626	302	26.2	1.0		1676	352	1.7	0.1	
1627	97	18.2	1.8		1677	365	0.3	0.0	
1628	25	21.0	2.5		1678	365	0.2	0.0	
1629	68	17.2	1.8		1679	365	0.0	0.0	
1630	14	0.0	0.0		1680	366	0.8	0.0	
1631	65	3.2	0.3		1681	365	0.0	0.0	
1632	366	0.0	0.0		1682	365	0.0	0.0	
1633	111	4.3	0.4		1683	365	0.0	0.0	
1634	339	1.6	0.0		1684	366	1.4	0.1	
1635	282	1.7	0.1		1685	365	0.0	0.0	
1636	0				1686	365	0.6	0.0	
1637	0				1687	365	0.1	0.0	
1638	334	69.2	2.2		1688	366	0.5	0.0	
1639	365	76.7	2.2		1689	365	0.2	0.0	
1640	2	15.0	1.9		1690	365	0.0	0.0	
1641	0				1691	365	0.0	0.0	
1642	37	50.4	5.9		1692	358	0.0	0.0	
1643	177	15.4	1.1		1693	365	0.0	0.0	
1644	250	12.0	0.6		1694	365	0.0	0.0	
1645	351	0.0	0.0		1695	365	0.1	0.0	
1646	365	0.0	0.0		1696	366	0.0	0.0	
1647	365	0.0	0.0		1697	365	0.0	0.0	
1648	366	0.0	0.0		1698	365	0.0	0.0	
1649	365	0.0	0.0		1699	365	0.0	0.0	

Year	D	R_G	sig	R_Z	Year	D	R_G	sig	R_Z
1700	365	0.4	0.0	5.0	1750	115	49.4	8.1	83.4
1701	365	0.5	0.0	11.0	1751	141	35.2	5.6	47.7
1702	365	0.6	0.0	16.0	1752	133	29.0	4.7	47.8
1703	365	2.7	0.1	23.0	1753	21	21.3	3.9	30.7
1704	358	4.1	0.2	36.0	1754	283	10.4	1.5	12.2
1705	365	5.5	0.2	58.0	1755	365	4.7	0.7	9.6
1706	365	3.2	0.1	29.0	1756	316	7.4	1.0	10.2
1707	365	5.3	0.2	20.0	1757	211	19.2	2.9	32.4
1708	361	2.9	0.1	10.0	1758	107	37.8	6.3	47.6
1709	365	1.6	0.1	8.0	1759	17	50.8	9.4	54.0
1710	365	0.4	0.0	3.0	1760	88	42.4	7.2	62.9
1711	365	0.0	0.0	0.0	1761	246	74.0	10.8	85.9
1712	366	0.0	0.0	0.0	1762	257	46.1	6.7	61.2
1713	365	0.3	0.0	2.0	1763	210	32.2	4.8	45.1
1714	346	1.0	0.0	11.0	1764	186	28.6	4.4	36.4
1715	354	3.6	0.1	27.0	1765	139	6.8	1.1	20.9
1716	353	9.1	0.4	47.0	1766	186	4.3	0.7	11.4
1717	365	17.4	0.7	63.0	1767	306	33.0	4.7	37.8
1718	254	10.0	0.6	60.0	1768	313	71.3	10.1	69.8
1719	342	33.8	1.4	39.0	1769	280	102.4	14.7	106.1
1720	344	23.9	1.0	28.0	1770	325	96.3	13.6	100.8
1721	308	17.6	0.8	26.0	1771	248	82.6	12.1	81.6
1722	103	10.9	1.1	22.0	1772	219	65.3	9.7	66.5
1723	9	7.9	1.0	11.0	1773	282	30.5	4.4	34.8
1724	17	14.8	1.9	21.0	1774	271	25.1	3.6	30.6
1725	129	12.5	1.1	40.0	1775	338	5.6	0.8	7.0
1726	319	36.5	1.6	78.0	1776	299	12.5	1.8	19.8
1727	35	39.8	4.8	122.0	1777	180	34.8	5.4	92.5
1728	58	65.5	7.4	103.0	1778	154	53.1	8.4	154.4
1729	24	27.8	3.4	73.0	1779	38	80.2	14.4	125.9
1730	39	84.9	10.1	47.0	1780	25	66.0	12.0	84.8
1731	3	0.0	0.0	35.0	1781	39	70.2	12.6	68.1
1732	2	18.0	3.4	11.0	1782	22	24.0	4.4	38.5
1733	365	0.0	0.0	5.0	1783	19	22.7	4.2	22.8
1734	1	0.0	0.0	16.0	1784	5	4.8	0.9	10.2
1735	26	20.3	3.7	34.0	1785	28	21.6	3.9	24.1
1736	28	53.1	9.7	70.0	1786	68	53.3	9.2	82.9
1737	2	24.0	4.5	81.0	1787	59	85.6	15.0	132.0
1738	1	17.0	3.2	111.0	1788	47	83.2	14.8	130.9
1739	17	55.8	10.3	101.0	1789	20	78.2	14.4	118.1
1740	45	12.3	2.2	73.0	1790	13	90.5	16.8	89.9
1741	17	15.1	2.8	40.0	1791	24	44.3	8.1	66.6
1742	21	11.2	2.1	20.0	1792	4	42.0	7.9	60.0
1743	19	10.8	2.0	16.0	1793	12	19.5	3.6	46.9
1744	0			5.0	1794	70	39.4	6.8	41.0
1745	0			11.0	1795	129	22.6	3.7	21.3
1746	1	0.0	0.0	22.0	1796	257	11.9	1.7	16.0
1747	0			40.0	1797	258	6.5	0.9	6.4
1748	1	61.0	11.5	60.0	1798	279	3.4	0.2	4.1
1749	109	65.0	10.8	80.9	1799	256	4.8	0.3	6.8

Year	D	R_G	sig	R_Z	Year	D	R_G	sig	R_Z
1800	243	8.6	0.5	14.5	1850	365	55.0	2.2	66.6
1801	328	49.9	2.1	34.0	1851	365	58.1	0.6	64.5
1802	257	34.0	1.9	45.0	1852	366	49.8	0.5	54.1
1803	252	18.4	1.0	43.1	1853	365	35.6	0.4	39.0
1804	266	21.4	1.1	47.5	1854	365	17.3	0.2	20.6
1805	184	19.8	1.5	42.2	1855	365	4.5	0.0	6.7
1806	88	21.0	2.2	28.1	1856	366	3.1	0.0	4.3
1807	250	2.3	0.1	10.1	1857	365	17.4	0.2	22.7
1808	302	2.8	0.1	8.1	1858	365	44.4	0.4	54.8
1809	348	1.2	0.0	2.5	1859	365	75.6	0.8	93.8
1810	365	0.0	0.0	0.0	1860	366	85.6	0.8	95.8
1811	365	0.3	0.0	1.4	1861	365	70.7	0.7	77.2
1812	352	3.9	0.2	5.0	1862	365	50.5	0.5	59.1
1813	365	9.1	0.4	12.2	1863	365	40.9	0.4	44.0
1814	347	10.6	0.4	13.9	1864	366	34.5	0.3	47.0
1815	332	17.0	0.7	35.4	1865	365	22.6	0.2	30.5
1816	336	31.3	1.3	45.8	1866	365	13.7	0.1	16.3
1817	355	28.2	1.2	41.1	1867	365	6.2	0.1	7.3
1818	358	21.9	0.9	30.1	1868	366	28.9	0.3	37.6
1819	365	19.3	0.8	23.9	1869	365	62.3	0.6	74.0
1820	338	10.7	0.4	15.6	1870	365	96.2	1.0	139.0
1821	352	4.1	0.2	6.6	1871	365	86.9	0.9	111.2
1822	365	3.0	0.1	4.0	1872	366	80.1	0.8	101.6
1823	365	1.2	0.0	1.8	1873	365	51.7	0.5	66.2
1824	330	4.0	0.2	8.5	1874	365	35.0	0.3	44.7
1825	365	14.5	0.6	16.6	1875	365	15.5	0.2	17.0
1826	365	28.7	1.2	36.3	1876	366	9.1	0.1	11.3
1827	365	44.4	1.8	49.6	1877	365	8.5	0.1	12.4
1828	366	57.1	2.3	64.2	1878	365	2.7	0.0	3.4
1829	365	59.3	2.4	67.0	1879	365	4.4	0.0	6.0
1830	359	64.0	2.6	70.9	1880	366	24.8	0.2	32.3
1831	365	39.3	1.6	47.8	1881	365	45.2	0.4	54.3
1832	366	22.6	0.9	27.5	1882	365	47.9	0.5	59.7
1833	365	6.5	0.3	8.5	1883	365	54.7	0.5	63.7
1834	358	9.4	0.4	13.2	1884	366	61.7	0.6	63.5
1835	365	46.3	1.9	56.9	1885	365	47.3	0.5	52.2
1836	360	99.5	4.0	121.5	1886	365	22.6	0.2	25.4
1837	330	109.9	4.7	138.3	1887	365	12.7	0.1	13.1
1838	336	76.8	3.2	103.2	1888	366	7.6	0.1	6.8
1839	346	65.5	2.7	85.7	1889	365	5.8	0.1	6.3
1840	360	47.9	1.9	64.6	1890	365	7.8	0.1	7.1
1841	365	26.6	1.1	36.7	1891	365	38.9	0.4	35.6
1842	365	18.8	0.8	24.2	1892	366	68.3	0.7	73.0
1843	355	8.2	0.3	10.7	1893	365	87.9	0.9	85.1
1844	366	11.9	0.5	15.0	1894	365	88.0	0.9	78.0
1845	365	29.8	1.2	40.1	1895	365	69.2	0.7	64.0
1846	347	43.6	1.8	61.5	1896	366	39.7	0.4	41.8
1847	352	58.9	2.4	98.5	1897	365	30.6	0.3	26.2
1848	366	86.0	3.5	124.7	1898	365	26.0	0.3	26.7
1849	365	83.4	3.4	96.3	1899	365	12.3	0.1	12.1

Year	*D*	R_G	sig	R_Z	Year	*D*	R_G	sig	R_Z
1900	366	9.1	0.1	9.5	1950	365	76.0	0.8	83.9
1901	365	2.5	0.0	2.7	1951	365	58.3	0.6	69.4
1902	365	3.8	0.0	5.0	1952	366	29.6	0.3	31.5
1903	365	24.1	0.2	24.4	1953	365	13.6	0.1	13.9
1904	366	45.3	0.4	42.0	1954	365	4.4	0.0	4.4
1905	365	61.0	0.6	63.5	1955	365	38.1	0.4	38.0
1906	365	56.2	0.6	53.8	1956	366	126.2	1.3	141.7
1907	365	61.4	0.6	62.0	1957	365	165.9	1.6	190.2
1908	366	53.1	0.5	48.5	1958	365	175.1	1.7	184.8
1909	365	46.4	0.5	43.9	1959	365	149.5	1.5	159.0
1910	365	21.5	0.2	18.6	1960	366	103.8	1.0	112.3
1911	365	8.5	0.1	5.7	1961	365	49.1	0.5	53.9
1912	366	3.6	0.0	3.6	1962	365	31.4	0.3	37.6
1913	365	1.6	0.0	1.4	1963	365	24.5	0.2	27.9
1914	365	12.4	0.1	9.6	1964	366	10.2	0.1	10.2
1915	365	50.6	0.5	47.4	1965	365	14.6	0.1	15.1
1916	366	67.1	0.7	57.1	1966	365	43.8	0.4	47.0
1917	365	110.1	1.1	103.9	1967	365	95.8	0.9	93.8
1918	365	89.2	0.9	80.6	1968	366	98.2	1.0	105.9
1919	365	71.6	0.7	63.6	1969	365	96.0	1.0	105.5
1920	366	43.5	0.4	37.6	1970	365	108.5	1.1	104.5
1921	365	28.6	0.3	26.1	1971	365	73.5	0.7	66.6
1922	365	15.8	0.2	14.2	1972	366	72.0	0.7	68.9
1923	365	6.9	0.1	5.8	1973	365	39.3	0.4	38.0
1924	366	18.2	0.2	16.7	1974	365	34.0	0.3	34.5
1925	365	51.2	0.5	44.3	1975	365	15.1	0.1	15.5
1926	365	70.8	0.7	63.9	1976	366	13.5	0.1	12.6
1927	365	77.6	0.8	69.0	1977	365	30.1	0.3	27.5
1928	366	82.3	0.8	77.8	1978	365	102.7	1.0	92.5
1929	365	74.4	0.7	64.9	1979	365	155.7	1.5	155.4
1930	365	44.2	0.4	35.7	1980	366	141.1	1.4	154.6
1931	365	26.0	0.3	21.2	1981	365	140.9	1.4	140.4
1932	366	13.5	0.1	11.1	1982	365	116.4	1.2	115.9
1933	365	5.9	0.1	5.7	1983	365	71.6	0.7	66.6
1934	365	10.4	0.1	8.7	1984	366	44.0	0.4	45.9
1935	365	42.8	0.4	36.1	1985	365	16.9	0.2	17.9
1936	366	88.8	0.9	79.7	1986	365	12.1	0.1	13.4
1937	365	120.6	1.2	114.4	1987	365	27.6	0.3	29.2
1938	365	113.6	1.1	109.6	1988	366	89.3	0.9	100.2
1939	365	97.3	1.0	88.8	1989	365	147.7	1.5	157.7
1940	366	71.7	0.7	67.8	1990	365	148.5	1.5	141.8
1941	365	49.9	0.5	47.5	1991	365	146.2	1.5	145.2
1942	365	32.8	0.3	30.6	1992	366	96.2	1.0	94.4
1943	365	15.5	0.2	16.3	1993	365	53.9	0.5	54.6
1944	366	10.7	0.1	9.6	1994	365	35.7	0.4	29.9
1945	365	37.3	0.4	33.2	1995	365	19.0	0.2	19.1
1946	365	95.2	0.9	92.6	1996				
1947	365	144.9	1.4	151.6	1997				
1948	366	127.5	1.3	136.3	1998				
1949	365	129.3	1.3	134.7	1999				

Notes to Appendix 2:

Year = year A.D.
D = number of observing days.
R_G = yearly mean Groups Sunspot Number computed using monthly means.
sig = one standard deviation uncertainty in yearly mean.
R_Z = yearly mean Wolf Sunspot Number computed using monthly means.