# AAVSO SOLAR DIVISION DIGITAL DATA ARCHIVES AT NGDC

**Helen E. Coffey**
**Christine D. Hanchett**
**Edward H. Erwin**
NOAA, National Geophysical Data Center (NGDC)
World Data Center A for Solar-Terrestrial Physics
325 Broadway
Boulder, CO 80303

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## Abstract

The American Association of Variable Star Observers (AAVSO) Solar Division has maintained an active observing program for many years in the solar-terrestrial physics disciplines. Both the American sunspot number $R_a$ and the Sudden Ionospheric Disturbances (SIDs) are monitored routinely by an AAVSO worldwide network of observers. The data are compiled at a central point by a dedicated observer who merges all of the reduced data reports from the worldwide network and quality controls these records. A copy of these are sent to the National Oceanic and Atmospheric Administration (NOAA) National Geophysical Data Center (NGDC) in Boulder, Colorado, who archives and disseminates solar-terrestrial physics datasets. The NGDC archives for the $R_a$ reach back to 1946 and provide a valuable independent measure of the sunspot number. The SID reports from AAVSO begin in 1958 when the NGDC SID archive begins. We review these archives in the context of the National Space Weather Program.*

## 1. Introduction

For many years the Solar Division of the AAVSO has routinely contributed both the computed American Sunspot Number $R_a$ observations and the SID observations to the NOAA NGDC for inclusion in their monthly publication, *Solar-Geophysical Data* (SGD), and to supplement the national/international data archives. $R_a$ was developed when the Zurich sunspot number was no longer available during World War II. This sunspot number is a critical component in determining the radio frequencies available for communication purposes. They are published in SGD (and its predecessor, Central Radio Propagation Laboratory, Part B) starting with the January 1949 data. Reduced SID recordings became routinely available during the International Geophysical Year (IGY) 1957–1958, when a concerted effort was made by the international scientific community to monitor the Earth's environment. These SID data are a critical piece of information when troubleshooting communications problems.

The AAVSO $R_a$ and SID effort continues to this day, coordinated through the help of the Solar Division Chairs, who over the years have included Harry L. Bondy, Casper H. Hossfield, Robert B. Ammons, Peter O. Taylor, Elizabeth Stephenson, and Joseph D. Lawrence. The routine measurements of $R_a$ and SID over many years have contributed substantially to space weather research. Improvements in technology and observer education are part of the AAVSO program. Joseph Lawrence recently renovated the SID data reduction processing, adding personal computer (PC) interactive software that aids in scaling these data and automatically formatting the data to the NGDC archive

* For on-line data, see http://www.ngdc.noaa.gov/stp. Click on the Solar and Upper Atmosphere icon, then on the Get Data icon to access solar data.

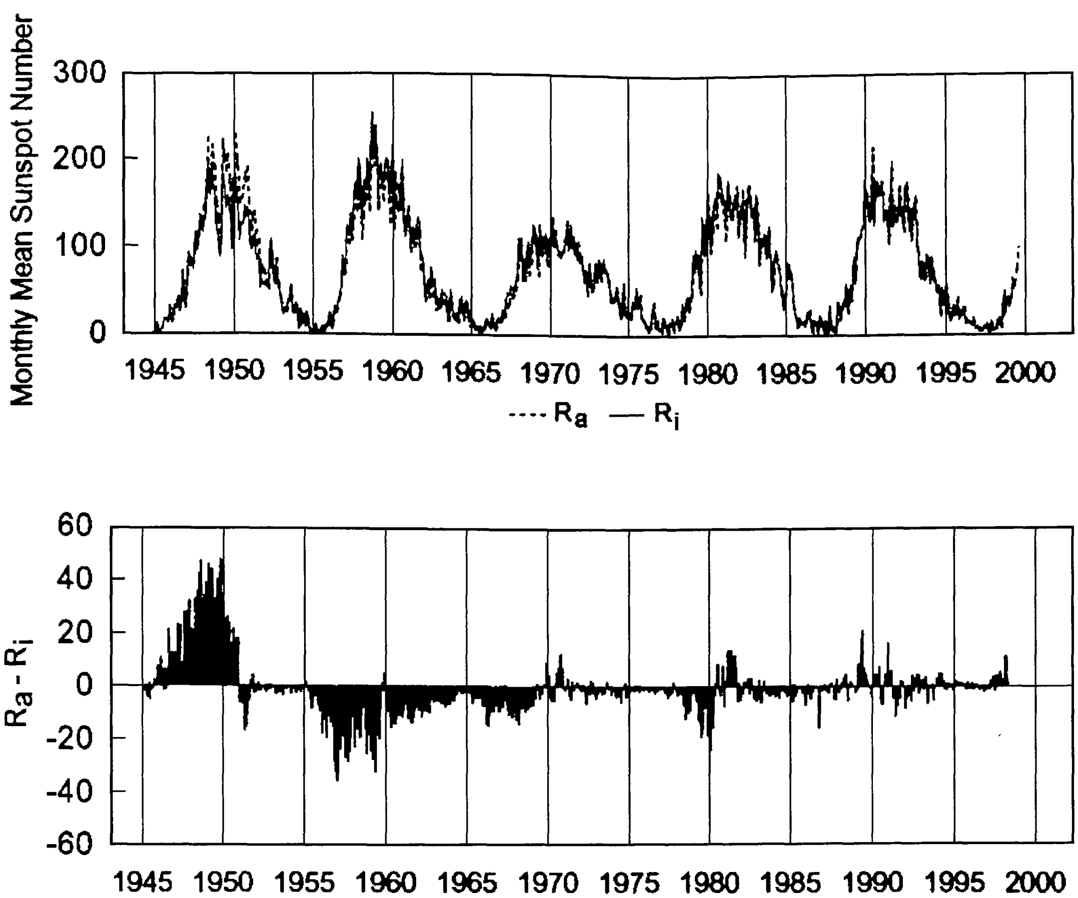


Figure 1. The top panel shows the close relationship between $R_a$ and $R_i$ monthly means for the period 1945–1998. The lower panel shows the monthly mean differences between the two numbers ($R_a - R_i$).

format.

Donald Trombino, an AAVSO member, gave an interesting talk at the NOAA Space Environment Center (SEC) Hazards of Space Weather Users Conference in April, 1998, in Boulder, Colorado, about the amateur solar observer networks. Trombino himself has a network link at Stetson University for the rapid transfer of solar imagery. He archives images every 20 seconds and makes them available on line. These include White Light, Ca, K, and Hα observations taken at an observatory in Florida.

NGDC maintains archives in solar-terrestrial physics disciplines, including solar and ionospheric databases. The AAVSO routine contributions of $R_a$ and SIDs appear in SGD. This monthly publication will go on-line in the near future, enabling a wider community to access these data. NGDC also maintains an ftp anonymous on-line digital data server, which includes the $R_a$ and SIDs.*

* The ftp address is ftp.ngdc.noaa.gov, then change directory to STP/SOLAR_DATA. From the Internet, go to the home page www.ngdc.noaa.gov, click on the Solar and Upper Atmosphere icon, then on the Get Data icon. To access the digital $R_a$ data, click on SUNSPOT_NUMBERS, then scroll down to AMERICAN_NUMBERS. To access the SID data, click on SIDs. The AAVSO SID data are included in the yearly files with all other reports received. See the SID_Stations for a listing of stations reporting.

## 2. American Sunspot Number ($R_a$)

Alan Shapley, NOAA, developed the $R_a$ data reduction procedure. Figure 1 shows the close relationship between $R_a$ and the International Sunspot Number $R_i$ (previously known as the Zurich sunspot number). The monthly mean differences are plotted in the lower panel of Figure 1.

Shapley noted the gradual inflation of values in the late 1940's and added a W weighting-factor to offset this. His technique is discussed in Peter Taylor's book (1991). Bradley Schaefer, Yale University (1993), notes a 0.3% inflation of values every time the K coefficients are calculated. This inflation problem is being addressed by the current AAVSO Solar Division.

Using SPSS 8.0 for Windows, we ran a correlation between the American Sunspot Number and the International Sunspot Number, using the available 641 monthly averages. The relationship between these two databases is:

$$R_i = 3.578 + 0.96\,R_a \qquad (1)$$

The correlation is 0.983. The mean $R_i$ = 76.08 (±57.02) and the mean $R_a$ = 75.26 (±58.15) (see Figure 2). These values compare similarly with those done by others (c.f. Foster 1997) and will vary depending on the number of values included in the statistical analysis as well as the rounding done by the statistical software.

Interestingly, a drop in frequency of values between 60 and 80 is also seen in the SID and solar x-ray data as shown later, suggesting a real physical phenomenon. It is quite possible that this drop reflects the quick rise to solar maximum seen in solar cycle behavior, when fewer values of mid-level activity are seen. This behavior may help with predicting the current solar cycle activity, since we are now moving through this fast rise period.

The number of observers for $R_a$ and $R_i$ has changed over the years, as well as the actual observers. The difficulties in computing the sunspot number are discussed in Hoyt and Schatten (1998). They opted to compile a group sunspot number that essentially counts only the numbers of groups on the Sun's surface, thereby avoiding the

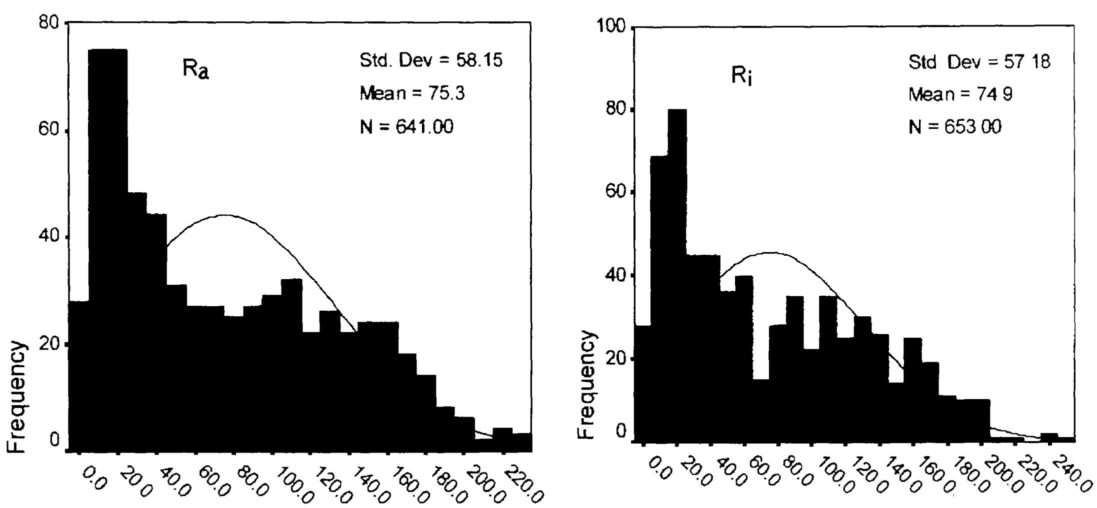


Figure 2. Plot of the frequency distributions of $R_a$ (left) and $R_i$ (right). These are the frequencies of the actual sunspot number values reported by the AAVSO and the Sunspot Index Data Center, and show a comparison of the internal structure of the two databases. The curves represent a Gaussian distribution.

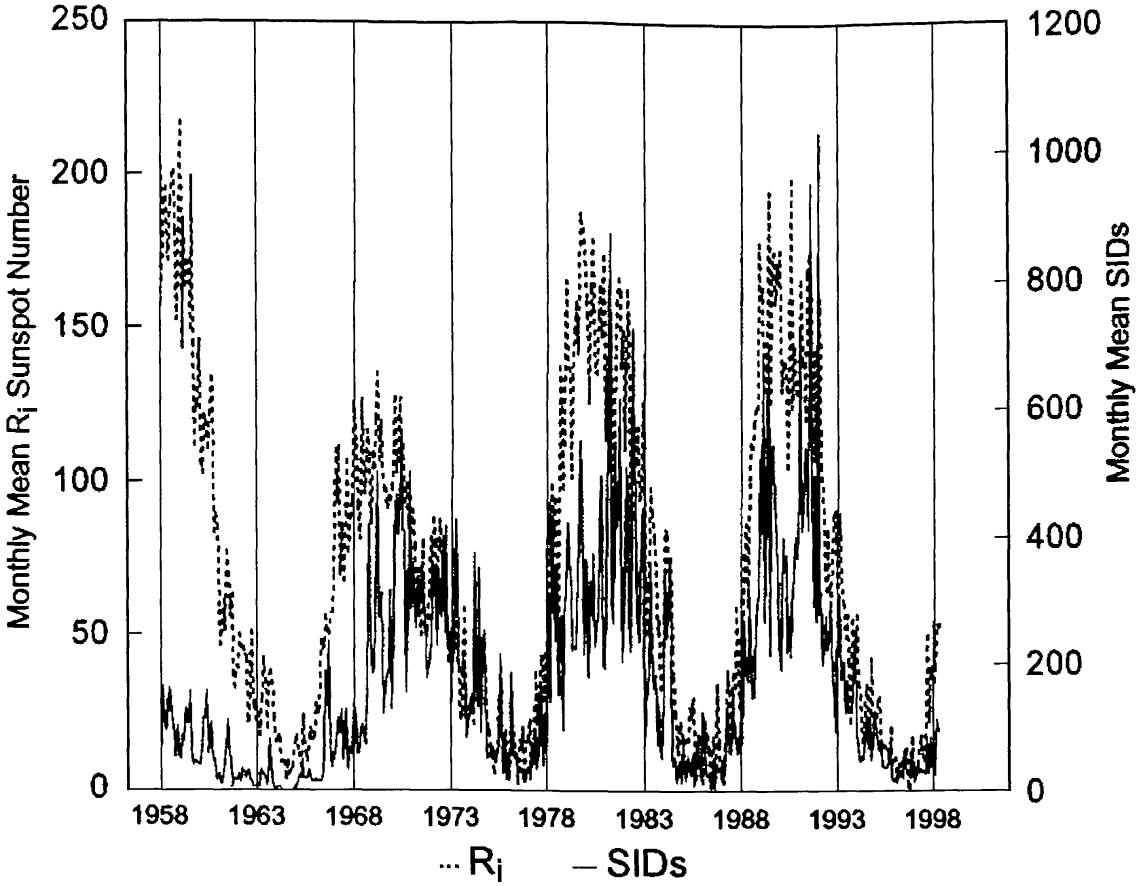


Figure 3. This plot of the monthly means of $R_i$ and SID data for the period 1958–1998 shows the 0.625 correlation between these two data sets. While both show the solar cycle, their behavior during solar maximum years differs somewhat.

extreme variability seen in the counts of individual sunspots within a group. Hoyt and Schatten do not propose to keep their group sunspot number current—data are available through 1995. Their group sunspot number is scaled to the $R_i$ values, and both databases are similar in recent years. The National Aeronautical and Space Administration (NASA) Solar Cycle 23 Project, of which Ken Schatten is a panel member (see www.sec.noaa.gov/info/Cycle23.html), uses the sunspot number and 10.7-cm solar radio flux in their prediction efforts for this new solar cycle.

Are the International sunspot numbers $R_i$ the better set of numbers? Every piece of data has a story behind it. There is a large spectrum between good data and bad data. We often find that key parameters used in research are not always the most homogeneous reliable data sets. However, they point to trends in physical phenomena that are usually further investigated with other kinds of data. Perhaps the future of sunspot numbers is a digital system that automatically reduces the number of spots observed, thereby minimizing human errors. It is noted that there is an extremely high correlation (0.98) between the subjective $R_i$ and the mechanically-measured solar radio flux at 2800 MHZ from Penticton (formerly Ottawa) for the time period when both data sets exist (1947–1998). Despite its subjectivity, the sunspot number certainly points to the trend of increasing and decreasing solar activity.

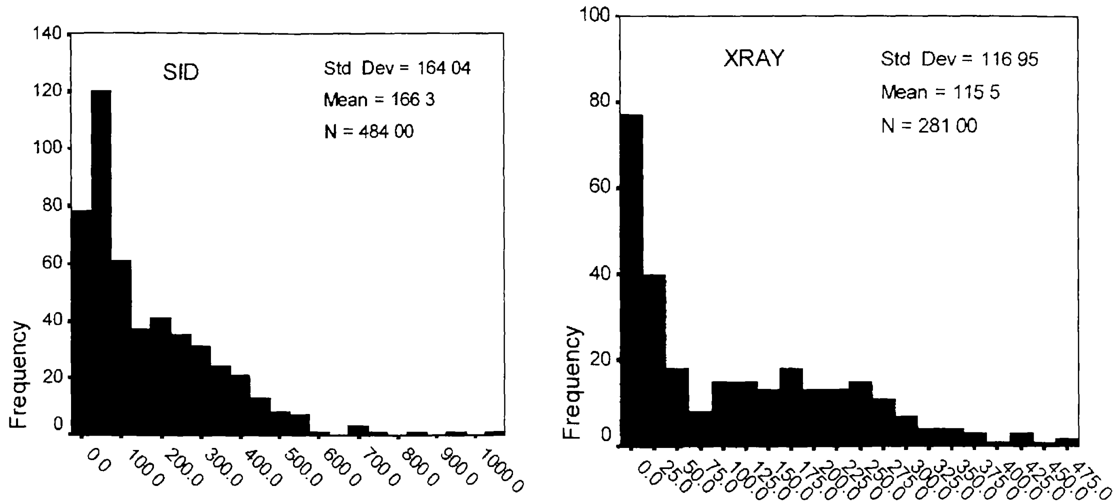


Figure 4. Frequency plots of the distribution of occurrence of the number of SID events (left) each month and the monthly mean number of X-ray events (right) are shown here. Again, notice a lower frequency of occurrence of X-ray events between the values of 50 and 75, as well as a slight minimum in SID frequency between 100 and 200. This again suggests a physical phenomenon.

## 3. Sudden Ionospheric Disturbances (SID)

AAVSO has contributed SID data to the NGDC archives since 1958, when the SID archive began. Figure 3 plots the $R_i$ and SID monthly means. While the solar cycle trends are apparent, the SIDs favor a double peak cycle maximum, more in line with the X-ray event distribution. The number of SID events each month was calculated using a quick and dirty program that merely counted all reports within a 15-minute time period as one event. This is a very rough estimate of specific events and in fact overcounts the numbers of events during high solar activity.

Using SPSS 8.0 for Windows, we find the following:

Correlation of SID with $R_i$: 0.625 — 484 points

Correlation of SID with the number of X-ray flares: 0.795 — 280 points

The relationship between $R_i$ and SIDs is: $R_i = 38.155 + 0.209$ SID

The relationship between XRAYs and SIDs is: XRAY = 16.048 + 0.514 SID

Figure 4 shows frequency plots of the monthly number of SIDs and the monthly mean number of X-ray flares.

One might expect the higher correlation of SIDs with the X-ray flare data, since the X-ray flares cause SIDs. Much work needs to be done with the SID database to control quality. One study by Parker and Bowhill (1986) indicates that the distribution of SIDs of importance 3 for the years 1980–1983 show a peak in the number of SID events when it is noontime in the U.S. It remains to be seen whether this noon peak is a manifestation of observers being more conscientious in the U.S. sector, or whether it is a physical phenomenon akin to the Global Electric Circuit that shows a peak at 2 pm U.S. time because of ionospheric effects of many thunderstorms in Brazil's Amazon region. The SID database is an integral part of the Comprehensive Solar Flare Index computed by Helen Dodson-Prince and Ruth Hedeman, McMath Solar Observatory. It is useful today as another window on the Sun's activity.

## 4. Conclusions

Maintaining historical archives is essential to our understanding of the Sun and our ability to forecast future activity. As technology increasingly produces smaller and smaller computer chips for use on board satellites, and as humankind moves into the space environment, it becomes more critical to understand space weather* and be prepared for disastrous events. Observations by amateurs provide an important counterpart to professional observatory results, being impervious to scientific budget crunches or scientific fads, depending mainly on the dedication and know-how of an interested and interesting core of observers motivated by a search for knowledge and contributing to an international effort to understand our environment. The dedication of these individuals over many years is gratefully acknowledged.

## References

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* For more information about space weather and its effects on Earth, please see the web sites www.geo.nsf.gov/atm/nswp/nswp.htm for the National Space Weather Program, and www-ssi.colorado.edu/Outreach/PlanningForMissions/SpaceWeatherOutreach/1. html for the Space Weather Outreach Project. Other web sites can be found by clicking on *Other Servers of Interest* on the www.ngdc.noaa.gov/stp home page.