How Sunspot Numbers Are Determined

The solar cycles from 1880 to 2010 are shown in Figure 1. The vertical scale on the left side of the graph is the number of sunspots observed each day. Note that the

- Amplitude (the maximum number of visible sunspots),
- Shape, and
- Duration

vary considerably from one cycle to the next.

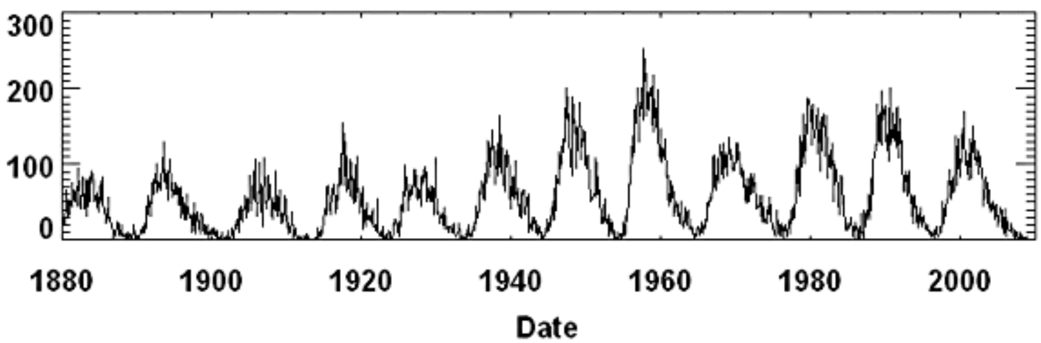

Figure 1 Solar cycles from 1880 to 2010 (credit: SpaceWeather.com)

One would think that producing the solar cycle graph is a straight forward process. You simply point a telescope at the Sun and record the number of sunspots observed.

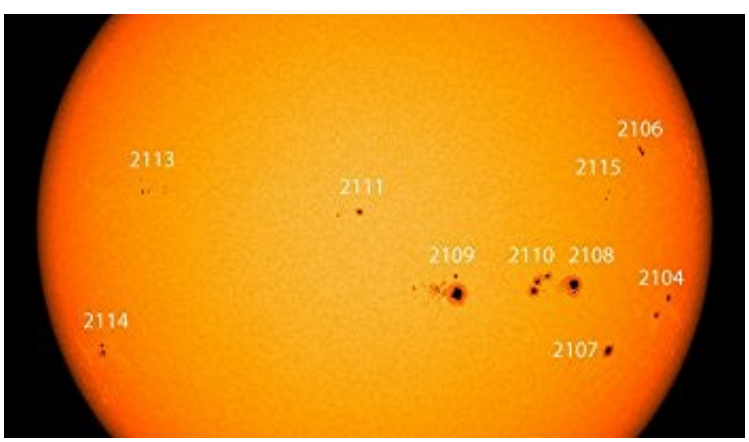

Figure 2 Sunspots on the face of the Sun (credit: NOAA Space Weather Prediction Center)

For example, in Figure 2 there are ten sunspot groups each of which is identified by a unique number. A sunspot group usually contains several individual sunspots. If you look carefully in this figure you can count maybe 23 individual sunspots. So we would expect from this figure that the sunspot number for this particular day is 23.

However, it turns out that determining the sunspot number is more difficult than we assumed in the above example.

If you look at the Sun through a low power home telescope, **with a strong solar filter carefully attached to the telescope to protect your eyes**, you might see three or four large sunspots. A high powered observatory telescope may see 10 to 25 sunspots, while a solar telescope in orbit could observe perhaps 50 to 100 sunspots.

So what is the correct number of sunspots, and more importantly, how do we correlate today's numbers with sunspot observations made more than a hundred years ago? The equation used today in determining daily sunspot numbers (the number of sunspots seen on a given day) is based on a formula derived by Rudolph Wolf in 1848. This equation is

$$R = k(10g + s)$$

where

R = the relative sunspot number
g = the number of sunspot groups observed on the solar disk
s = the total number of individual spots observed, including those in sunspot groups
k = a variable scaling factor

The scaling factor k accounts for observing conditions and the particular telescope used. Wolf set k = 1 for the observations he made with his telescope at the Zurich observatory in 1849. Each observatory has its own assigned value of k which scales its observations to what Wolf would have observed using his 1849 telescope. Today k < 1 for most observatories, generally much less than 1.

Data from many different observatories, each with their own value of k, are combined together to arrive at a daily sunspot number. Two official sunspot numbers are in common use:

1. The daily "Boulder Sunspot Number" computed by the NOAA Space Environment Center

2. The "International Sunspot Number" published by Solar Influences Data Center in Belgium.

Two other sunspot numbers are important in addition to the daily sunspot number. These are

- The monthly mean sunspot number R_m, and

- The smoothed monthly sunspot number R_s .

The monthly mean sunspot number is the average number of sunspots for the month. That is, the monthly mean sunspot number is

$$R_m = \frac{R_1 + R_2 + R_3 + \cdots + R_n}{n}$$

where

R_1 = the daily sunspot number for the first day of the month

R_2 = the daily sunspot number for the second day of the month, etc.

n = the number of days in the month

The smoothed monthly sunspot number R_s is the average of the monthly mean sunspot numbers over 13 months from 6 months before to 6 months after the month of interest m. All months have the same weighting except for the first and last months in the series (R_{m-6} and R_{m+6}) each of which is given a weighting of one half (0.5). Thus the smoothed monthly sunspot number

$$R_s = \left(\left[\sum_{m-5}^{m+5} (R_m) \right] + 0.5R_{m-6} + 0.5R_{m+6} \right) \Big/ 12$$

The smoothed monthly sunspot number is one of the most widely used index in ionospheric work.

Figure 3 compares the daily (yellow), monthly mean (blue), and smoothed monthly (red) sunspot numbers for Solar Cycle 24.

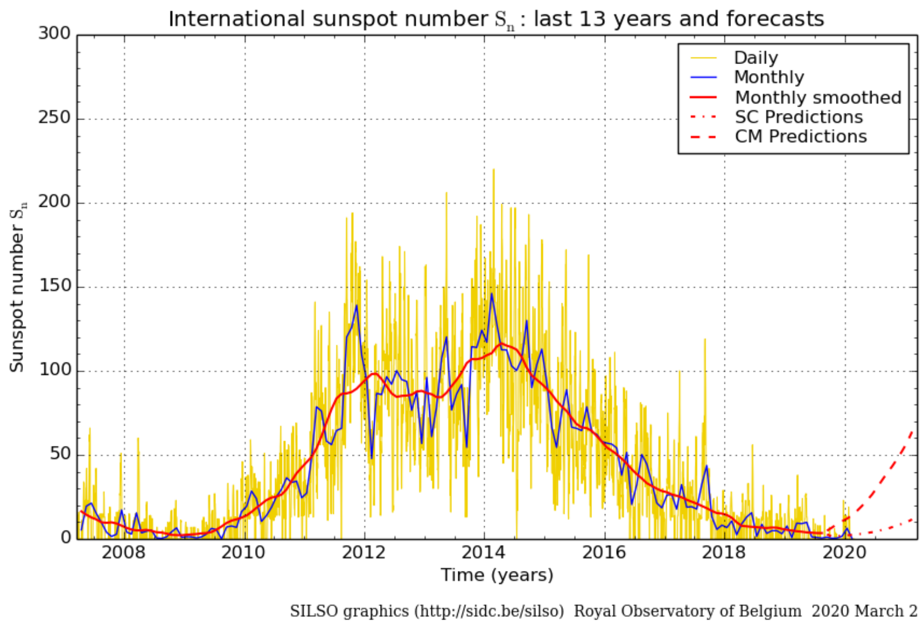

Figure 3 Solar sunspot numbers for Solar Cycle 24 (credit: SILSO graphics http://sidc.be/silso)

While the Wolf equation is simplistic, it compares remarkably well with more complex measurements of solar activity based on current technology.

One of the techniques extensively used today is background radio noise known as the Solar Flux Index (SFI). Random collisions of electrons with heavier particles produces this continuous solar radio noise which is measured by observatories every day at a frequency of 2,800 MHz (10.7 cm wavelength). The Solar Flux Index correlates well with measured levels of solar X-ray and Extreme Ultra Violate (EUV) radiation. It also correlates remarkably will with sunspot numbers as illustrated in Figure 4. In addition, Solar Flux Index is an excellent indicator of ionospheric conditions, including HF radio propagation through Earth's upper atmosphere. SFI numbers vary from a low of about 65 during solar minimum to around 225 at the peak of a solar cycle.

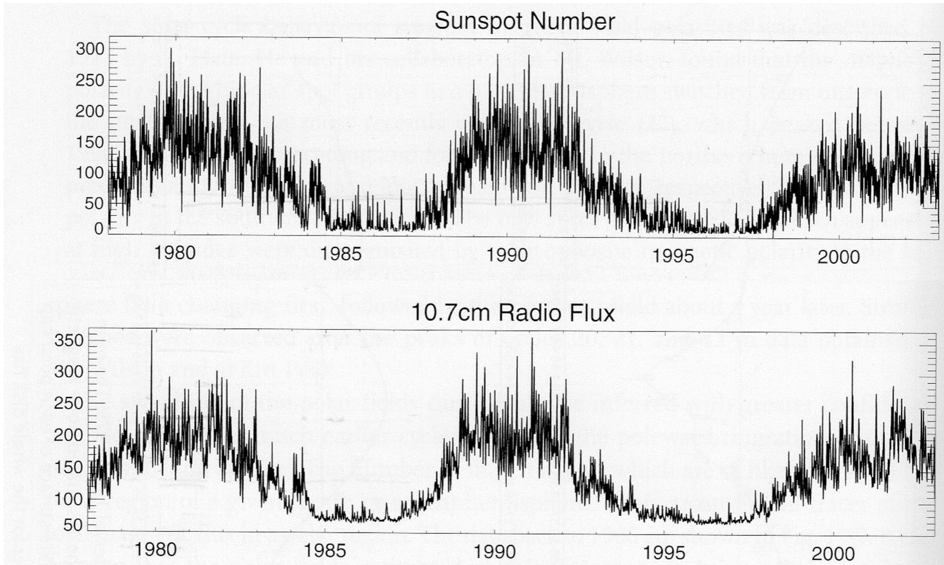

Figure 4 Radio flux vs Sunspot number (credit: G. deToma)