Looking at the Sun

K7LY discusses whether big peaks in daily sunspot numbers or the solar flux index are reliable indicators of good propagation.

John Keating, K7LY

Recent solar activity triggered numerous powerful solar flares, generated high levels of solar flux, and elevated geomagnetic activity. Those events piqued my curiosity about the interrelationships between measurement parameters and band conditions. In particular, I wondered what propagation hints we might glean from near-real-time solar figures and whether big peaks in daily sunspot numbers (SSNs) or solar flux indices (SFIs) were reliable indicators of good propagation — and if we should pay closer attention to those rather than to their averages. I put my spreadsheet skills to the test and combined certain datasets to derive intuitively understandable graphical analyses.

First, I wanted to see how much of a difference there was between the individual daily maximum sunspot values (such as what you might see displayed on **www.hamqsl.com** by Paul Herrman, NØNBH) and the smoothed or monthly averages (such as what's displayed on NOAA's Space Weather Prediction Center website at **www.swpc.noaa.gov**). Hams get excited about high sunspot numbers. Careful observation of Figure 1 shows that on some days, the SSN (marked by the blue peaks) can be double that of the smoothed value (marked by the dark line), and, historically, has even reached a value of more than 500! As is also apparent from Figure 1, smoothing eliminates the random day-to-day fluctuations of solar activity with the aim of bringing out the long-term trends and the general progress of the solar cycle. Smoothing essentially applies a "low-pass filter" to the original data series. Smoothing over 13 months is the standard for analysis because it provides a common base for comparison of long-term evolution of the solar dynamo and processes with long response times such as global circulation in planetary atmospheres. Solar flux is closely related to the amount of ionization, hence the electron concentration in the F2 region. As a result, it gives a very good indication of conditions for long-distance communication, as reported by Ian Poole, G3YWX, in his September 2002 *QST* article, "Understanding Solar Indices," but it depends on what time periods are used for comparison, as will be addressed next.

Exploring the Data

With the daily peak sunspot data in hand, let us consider the following questions, which can be addressed by parsing and correlating data from several large historical datasets.

Does the SFI correlate with the daily SSN?

As is generally understood, and visually apparent from Figure 2, there is a moderately strong correlation between the maximum daily observed SFI (marked by the red line) and the maximum daily SSN (marked by

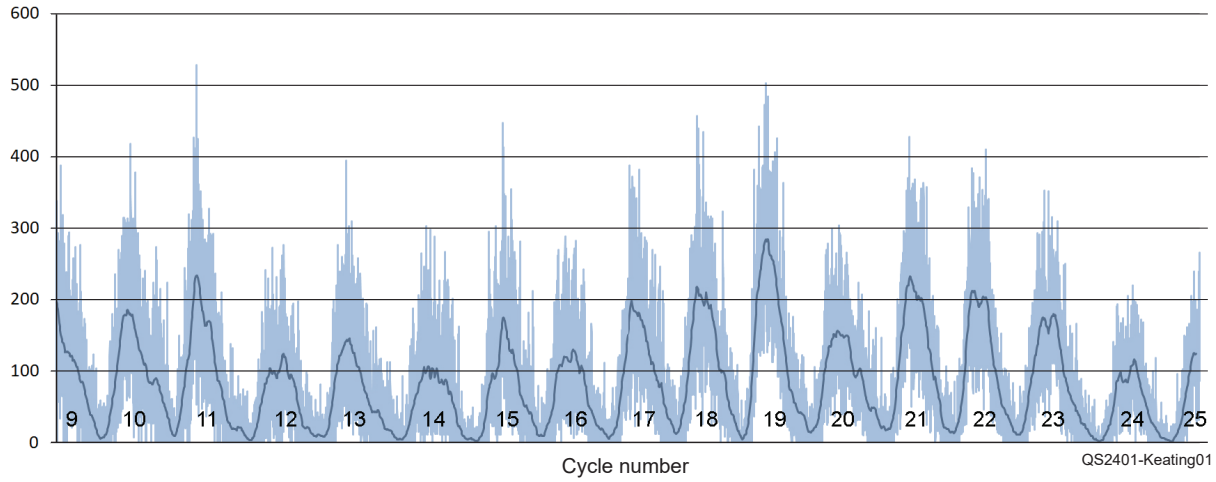

Figure 1 — The daily SSN (the blue peaks) and 13-month SSN (the dark line) for 1849 (Solar Cycle 9) through mid-2024 (Solar Cycle 25). [Source: **https://sidc.be/SILSO/datafiles**]

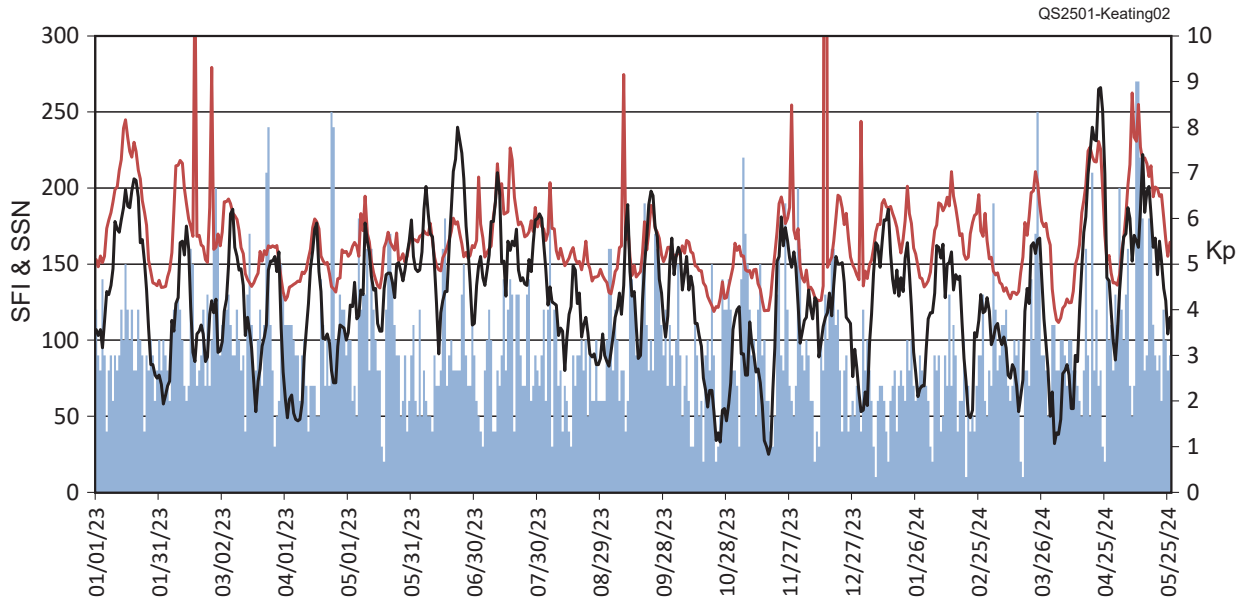

Figure 2 — Daily maximum solar flux (the red line), the SSN (the black line), and the Kp index (the blue peaks on the right axis) from January 2023 to May 2024. [Sources: **https://spaceweather.gc.ca**, **https://sidc.be/SILSO/datafiles**, and **https://kp.gfz-potsdam.de/en**]

the black line). Statistically, for the period of January 2023 to mid-May 2024, the correlation coefficient is $r = 0.62$.

Does a high SFI correlate with the daily high maximum usable frequency (MUF)?

As shown in Figure 3, from January 2022 to April 2024, there was a weak positive correlation ($r = 0.21$) for the daily maximum values, due in part to the high variability in daily peak MUF values and the large excursions, especially from May through August of those years. However, those data present a case for smoothing. Similarities in the timing and direction of the trends become apparent when overlaying 6th-order polynomial trend lines (which Excel conveniently calculates), as that technique provides a good fit for complex data with many local minima and maxima. One may therefore conclude that the longer-term timing and direction of the smoothed SFI and MUF peak data are consistent, whereas any particular day's peak SFI values should not create specific expectations regarding peak MUF on that day.

Is there a correlation between the SFI and the Kp index?

This relates to the possibility of geomagnetic disturbances correlating with high solar activity. Referring again to Figure 2, maximum daily Kp index data are marked by the blue peaks — those values vary extensively! The coefficient of correlation between the SFI (marked by the red line) and the Kp index is $r = 0.12$ (at most) for the Kp index values 3 days after the SFI data. Geomagnetic disturbances measured by Kp occur up to 5 days following a solar event, due to the time required for solar particles to travel to Earth's magnetosphere. When restricting the analysis to days in 2023 and 2024, during and after the occurrence of X-class flares, the correlation between the SFI and the Kp index is somewhat stronger (but still weak), at $r = 0.28$ for Kp index values, 3 days after the SFI data. Therefore, the daily peak SFI is a poor leading indicator of the daily peak Kp index. This can be explained by the fact that geomagnetic storms (measured by the Kp index) are produced almost exclusively by the Earth's passage of interplanetary disturbances driven by fast coronal mass ejections (CMEs), and about only 10% of CMEs spawned by flares reach Earth.

Is there a correlation between the Kp index and daily high MUF?

Not shown in the figures is a comparison of daily maxima of the Kp index and MUF for January 2022 through April 2024, which yields $r = -0.008$ — essentially no correlation. Correlation of those parameters is problematic because of the extremely spiky nature of the data. However, when the K index is high for a long time, the electron density in the F2 region of the ionosphere can be significantly depleted for days, not allowing higher frequencies to be propagated. That is somewhat apparent from the weak negative correlation ($r = -0.13$) between the 3-day moving average of the peak Kp index and the 3-day moving average of peak MUF, delayed 3 days from the Kp index average.

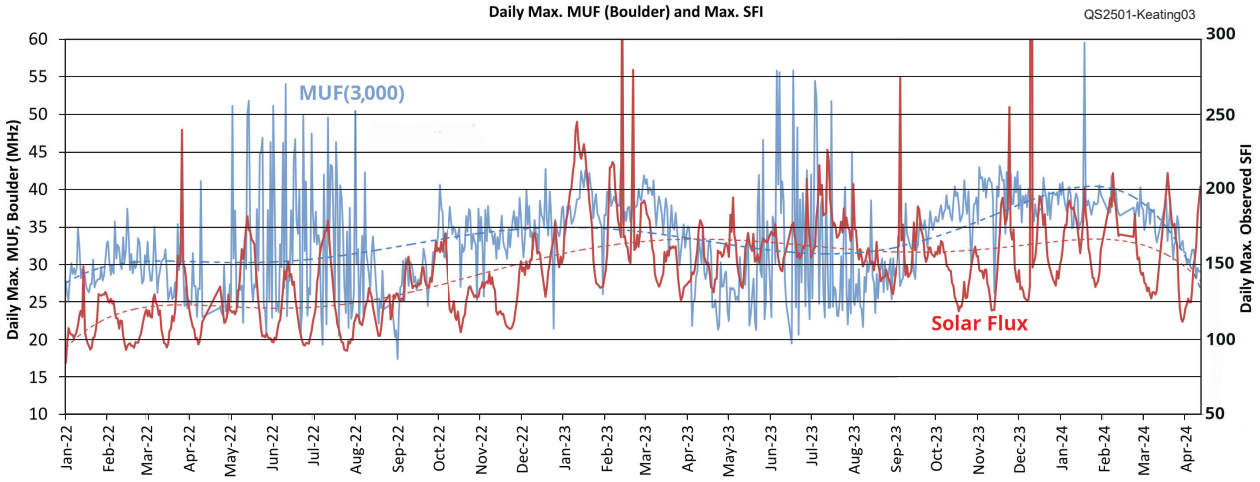

Figure 3 — Daily MUF (the blue line on the left axis) and maximum observed solar flux (the red line on the right axis) from January 2022 to April 2024, with 6th-order polynomial trend lines (the dashed lines). There are a few gaps in MUF data, which cause the SFI graph to differ slightly from Figure 2. [Sources: **https://spaceweather.gc.ca** and **https://giro.uml.edu/didbase/scaled.php**]

Conclusions

One can easily see the effect of the smoothing function on the daily peak sunspot values. Without the granular detail in Figure 1, one might have missed the 2 days where the maximum sunspot number exceeded 500 (August 29, 1870, and December 24, 1957), as well as other dates of interest. Similarly, wild swings in the SFI do not appear in the smoothed data. On the other hand, the peak SSN and peak SFI values do correlate pretty well, implying that one could reasonably serve as a proxy for the other. The key thing for hams to remember when looking at historical data is that the sun is a lot more variable than the smoothed data would imply.

As to the other points of analysis, peak daily SFI data in isolation doesn't imply anything about MUF. The similar directional trends of those parameters are apparent only when smoothed throughout relatively long periods. The peak SFI is weakly correlated with the Kp index, and, consequently, the SFI seems to have little relationship to geomagnetic disturbances. Finally, peak daily Kp index and MUF values are not correlated; therefore, any particular day's Kp index doesn't inform us of MUF, although longer-term samples, especially following periods of a high Kp index, may portend reduced MUF.

These analyses show that there isn't a good correlation among solar parameters and ionospheric conditions in the short term, which is why propagation predictions are statistical in nature and are based on smoothed solar indices and monthly medians.

Acknowledgments

I wish to express my appreciation and thanks to Frédéric Clette at the Royal Observatory of Belgium; Carl Luetzelschwab, K9LA, and Edward McCann, AG6CX, for their helpful suggestions and expert reviews.

See *QST* in Depth for More!

Visit www.arrl.org/qst-in-depth for the following supplementary materials and updates:

- ✓ Additional graphs
- ✓ Resources for further reading on the subject

John Keating, K7LY, recently retired after a career in the tech industry. He now has time to sort through mountains of data to produce charts, such as the ones in this article. When he needs a break from number crunching, he likes to operate SSB DX, build antennas, and restore vintage HF equipment. John can be reached at **k7ly@arrl.net**.