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Author Information

R. A. Houghton and S. J. Goetz, Woods Hole Research Center, Falmouth, Mass.; E-mail: rhoughton@whrc.org

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Not to Worry: Solar Magnetic Activity for Cycle 24 Is Increasing

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Several academic sources have noted that the current sunspot minimum seems to be unusually long. Indeed, sunspot counts are at a 50-year low. As of 27 September, the Sun has had no visible sunspots for 200 days this year, the most of any year since 1954. Unfortunately, this has been interpreted in some media sources as showing that there is something wrong with the Sun. Some reports have even suggested that we should prepare for a widespread cooling due to a lack of sunspots and even that a new mini ice age is on the way (see “Sorry to ruin the fun, but an ice age cometh,” by P. Chapman, at http://www.theaustralian.news.com.au/story/0,25197,23583376-5013480,00.html).

True, the total solar irradiance at Earth has dropped to a minimum that is lower than seen in the previous two cycles (see *Lockwood and Fröhlich* [2008] for a description of the trends in total solar irradiance). And the length of the minimum in solar activity may actually have some important implications. The most extreme solar minimum was the 70-year-long Maunder Minimum of 1645–1715 that coincided with the Little Ice Age. This period consisted of extremely severe winters in the Northern Hemisphere. While evidence such as this indicates a possible link between the solar cycle and Earth’s climate, it is not known what the mechanism could be.

Perhaps more pertinent to our current technology-based society is the fact that a less active Sun means fewer solar storms; solar storms pose a threat to astronauts and various satellites, including GPS and weather satellites. Further, radio bursts from solar flares can interfere with cell phones. The strongest solar storms are caused by coronal mass ejections (CMEs) hitting the Earth, and these events can even threaten ground-based electronics, aircraft navigation, and power grids. All of these events occur less frequently during solar minimum.

Yet there is nothing amiss with the current solar minimum. NASA solar physicist David Hathaway at the NASA Marshall Space Flight Center was quoted saying, “the ongoing lull in sunspot number is well within historic norms for the solar cycle” (see “What’s wrong with the Sun? (Nothing)” at http://science.nasa.gov/headlines/y2008/11jul_solarcycleupdate.htm). For example, there were 6 years in the past century with more spotless days than 2008, including 1913, which had more than 300 spotless days. Further, examination of the interplanetary magnetic field (IMF) activity supports this conclusion and shows that while the sunspot number may still be low, IMF activity this solar cycle appears to be increasing as expected, with solar maximum predicted for 2010.

Boxcar Averages of the Interplanetary Magnetic Field

IMF data can be analyzed in a manner identical to that used to calculate the sunspot number. This is important in that IMF activity is indicative of overall solar activity. In fact, IMF activity seems to lead the overall activity, presenting the possibility that it can serve as an early indicator of upcoming solar activity.

Keating et al. [2001] and *Keating and Jaeger* [2003] described how a long-term average, consisting of a smoothed, 13-month “boxcar” mean of the magnitude of the *z* component of the magnetic field ($B_z(m)$), demonstrated a cyclical pattern similar to the solar cycle with approximate correlation to the solar sunspot cycle. The boxcar method of averaging is useful for smoothing the data in order to eliminate short-term variations. The method consists of summing $B_z(m)$ averages of 11 consecutive months, beginning with the month 5 months prior to the month being examined and ending with the month 5 months after the month being examined. A final term is then added to this sum: one half of the data average for the month that falls 6 months previous plus one half of the data average for the month that falls 6 months following.

This method takes the average data from 13 months and yields a sum of 12 full months of averaged data. This sum is then divided by 12 to give a monthly running average $B_z(m)$. For instance, the boxcar average for June would consist of the sum

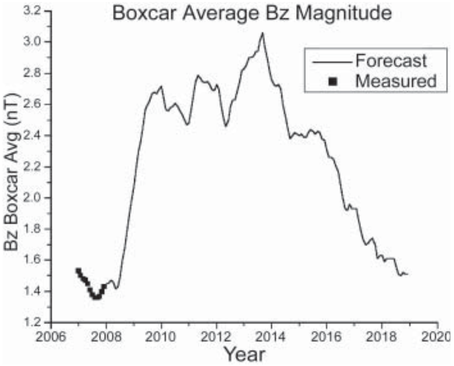

Fig. 1. Actual boxcar averages for measured B_z(m) *magnitude and the forecast results of applying the McNish-Lincoln technique. Actual data are represented by solid squares, while the calculated results are shown as a curve. The correlation between the two is due to the fact that the McNish-Lincoln method uses actual data when available. The calculated forecast is performed only for the time period after the end of the actual data. This plot shows that* B_z(m) *reached its minimum average magnitude in mid-2007 and has begun to increase in magnitude. The forecast is that it will continue to increase slowly through the first part of 2008, but will then begin to rapidly increase in magnitude beginning in the latter part of this year, reaching its first peak in late 2009.*

Table 1. Results of the McNish-Lincoln Technique Forecast for the $B_z(m)$ Boxcar Average Monthly Values for 2008 and 2009[a]

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	$B_z(m)$ averages	1.45	1.45	1.47	1.46	1.42	1.43	1.49	1.60	1.68	1.78	1.89	1.9
	Uncertainty	0.06	0.11	0.12	0.20	0.39	0.30	0.25	0.25	0.24	0.17	0.09	0.07
2009	$B_z(m)$ averages	2.08	2.19	2.30	2.37	2.46	2.57	2.60	2.63	2.67	2.68	2.67	2.70
	Uncertainty	0.12	0.11	0.13	0.16	0.14	0.11	0.22	0.27	0.26	0.27	0.28	0.36

[a] Adding and subtracting the uncertainty estimates to the predicted value yields the upper and lower bounds to the 90% confidence interval. All values are in nanoteslas.

of the monthly averages beginning with the previous January through the following November, plus one half of the monthly data averages for the previous and following Decembers, divided by 12. The weakness of this method is that the latest month it can provide an average for is the one 6 months prior to the end of the collected data, introducing a time lag in the analysis.

The IMF can change dramatically in magnitude in a very brief period of time, with quiescent periods intermixed with active ones. When we apply the boxcar average method to the IMF data, we are provided with a running, low-resolution average of the $B_z(m)$ magnitude that smoothes out these intermingled periods and reveals the underlying general trend. While such a low-resolution average does not reflect the polarity of the IMF, it does reflect the large-scale level of activity, showing the basic trend of the $B_z(m)$ activity without being distorted by fine structure detail. This is the same method used by the National Geophysical Data Center (NGDC) to smooth the sunspot number.

Plots of this average show that $B_z(m)$ typically starts to rise and fall before the sunspot number, even taking into account the 13-month smoothing, making it a potentially early indicator of solar activity.

Predicting Future Cycles

Keating et al. [2001] and *Keating and Jaeger* [2003] then proposed that the technique proposed by *McNish and Lincoln* [1949], and now used to forecast sunspot numbers, could also be used to make a forecast of IMF activity.

The McNish-Lincoln technique is a method of predicting future activity of any cyclical pattern and involves comparing a current cycle in a cyclic pattern to a composite of all previous cycles in the pattern. This method assumes that given a time series exhibiting cyclic tendencies, a first-order approximation of a future value for a period in the cycle is the mean of all past values for the same part of the cycle. If the mean behaved in a certain way at a given point after the onset of the cycle, then any given cycle will behave in approximately the same way at an equivalent point after the cycle onset. It is also assumed that this estimate can be improved by adding a least squares correction proportional to the departures of earlier values of the same cycle from their respective means. A more detailed description is provided by *Keating et al.* [2001].

The McNish-Lincoln method applied to the smoothed sunspot number provides reasonably accurate predictions for average sunspot numbers 12–24 months into the future and is provided monthly by NGDC. Beyond that, the forecast begins to conform to the composite average.

When Will the Current Sunspot Low End?

When the boxcar method and the McNish-Lincoln technique are used, the future of solar activity looks bright. The data used here were obtained from the National Space Science Data Center (NSSDC) via the OmniWeb and consisted of 391,177 hourly average IMF data points covering the period from 27 November 1963 to 17 June 2008. The data have broken periods in the beginning years, resulting in periods with no monthly average. For this reason we adjusted the division factor in the averaging technique for the early months to reflect the actual number of months that have a value for the monthly average.

The first month using averages from a full 13 months is January 1967. The averages for the 24 months from January 1965 through December 1966 are thus more susceptible to individual events. Additionally, we are now in only the fifth full cycle of IMF data, as compared with the 24th full cycle of sunspot data, so the forecast for IMF activity is more variable than for sunspot activity.

Table 1 shows the IMF forecast values and uncertainties for each month in 2008 and 2009. Adding and subtracting the uncertainty estimates to the predicted value yields the upper and lower bounds to the 90% confidence interval. For instance, the predicted value for January 2009 is 2.08 nanoteslas, plus or minus 0.12 nanoteslas. This means there is a 90% chance the actual smoothed average magnitude for that month will be between 1.96 and 2.20 nanoteslas.

Figure 1 presents the actual boxcar average calculations performed on available data, shown as solid squares, and the McNish-Lincoln forecast of future values, shown as a curve. The data show the cycle minimum was reached in late 2007 and the average IMF magnitude has now begun to increase, as expected for the current solar cycle. The forecast is that it will continue to increase slowly through 2008 but will then begin to rapidly increase in magnitude beginning in the latter part of this year, reaching its first peak in late 2009.

On the basis of this observed activity and using it as an early indicator of solar activity, we would expect to see the number of sunspots to begin increasing by the end of this year, or shortly thereafter.

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—C. F. KEATING, Physics Department, U.S. Naval Academy, Annapolis, Md.; E-mail: keating@usna.edu