Report

GEOMAGNETIC ACTIVITY AND VIOLENT BEHAVIOR

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ABSTRACT

This paper reports on a statistical study of hypothesized relationships between three indices of geomagnetic field activity and the incidence of violent crime on a nationwide basis, focusing on monthly variation over the entirety of an 11-year solar cycle, and yearly variation over a 30 year period encompassing the past three solar cycles (cycles 19, 20 and 21). Contrary to expectations, sunspot numbers — which have only a tenuous relationship with geomagnetic activity — were found to be significant at the yearly level, while none of the more direct indices of geomagnetic activity exhibited any correlation. The possibility of a non-magnetic solar effect on human behavior is therefore raised.

KEYWORDS: Geomagnetic, behavioral, sunspots

INTRODUCTION

It has been well established that energetic events associated with the sun produce disturbances in the Earth's magnetic field.[1] Such "magnetic storms" have long been postulated to exert an effect on human behavior; few attempts have been made, however, to scientifically evaluate this hypothesis. Düll and Düll's seminal work[2] reported on a study of "nervous disorders" in 40,000 patients over a 60 month period, relating this to magnetic storms. The authors did not, however, subject their data to statistical analysis. Thirty years later Friedman *et al.* demonstrated statistically significant relationships between behavioral disturbances among patients on psychiatric wards and activity in the geomagnetic field,[3] as well as the incidence of magnetic storms and admission to mental hospitals over a three year period.[4] None of these studies extended over a complete 11-year cycle of solar activity (see below), and all used geographically localized data. Primarily because a credible mechanism of action was unavailable, few serious attempts were subsequently made to relate geomagnetic disturbances associated with solar activity to human behavior. Since that time, biological mechanisms have been identified that directly relate organismal function to the status of the geomagnetic field and other static or quasi-static magnetic fields.

Recent studies have reported relationships between the geomagnetic field and biological cycles[5] and animal navigation.[6] These appear to be mediated by specific magnetic field receptors such as the magnetite-containing "magnetic organ"[7] and the retina/pineal gland system.[8] The latter has been shown to be associated with the diurnal production of melatonin, a potent neurohormonal agent that may be associated with behavior.[9] Most recently, Balaban[10] reported measurable effects of static magnetic fields upon neuronal function. These indications of a relationship between the quasi-static geomagnetic field and central nervous system-mediated activities are reinforced by a large volume of data indicating diverse bioeffects from man-made electromagnetic fields.[11] In this light, it was postulated that some relationship between behavior and the status of the geomagnetic field was possible. The earlier behavioral studies noted above used various measures of psychiatric disturbances (chiefly schizophrenia) as the dependent variable. The present availability and extensive clinical use of a variety of psychotropic drugs now renders this parameter unavailable.

It was hypothesized that a suitable surrogate measure might be the incidence of violent crime. While admittedly not an absolute characterization, crimes such as murder, non-negligent manslaughter and aggravated assault are more apt to represent spontaneous and transient behavioral abnormalities than criminal behavior more typically associated with a premeditated component. This paper reports a study of these parameters as they relate to a variety of solar and geophysical variables in solar cycles 19, 20 and 21, a period of 31 years.

Use of violent crime as the dependent variable is not unique to this study; perhaps most interesting of the previous work in this area was Leiber and Sherin's[12] correlation of the incidence of homicide with the lunar cycle, which may also have an impact on geomagnetic activity. Work in this area is, however, far from consistent. Pokorny and Jachimczyk[13] found no significant relationship between lunar activity and homicides, while Tasso and Miller[14] found that eight categories of criminal activity did occur more frequently "during the full moon phase than at other times of the year," but that "[o]nly the category of homicide did not occur more frequently during the full moon phase." The most direct precursor to the present study was Pokorny and Mefferd's[15] examination of the impact of fluctuations in the geomagnetic field and behavioral disturbances. Despite sophisticated analysis, the authors discovered no relationship between indices of magnetic activity and behavior.

METHODS

The Independent Variables

Solar activity, as measured by the number of sunspots, follows an approximately eleven-year cycle in which the incidence of magnetic disturbances gradually increases, reaches a maximum, then diminishes to another trough as the cycle begins again. Geomagnetic storms are the result of energetic events on the sun, which are more common during periods of high solar activity. If the hypothesis in question is correct, monthly variation in both solar and the resultant geomagnetic activity may be related to temporally discrete instances of aberrant behavior, while annual variation may be associated with general trends in the data (i.e, increases or decreases on an annual basis).

Three separate indicators were utilized. One is a broad index of solar activity, ***sunspot numbers***;[16] the number of sunspots present at the solar surface across a given time period was used as a measure of the progress of the 11-year solar cycle. The second, the aa-***index***, is a smoothed representation of the planetary magnetic field resulting from variations in solar magnetic activity.[17] An index of the number of *magnetic storms* served as the third variable.[18]

Monthly *aa* and sunspot indices represented the monthly mean of each index, respectively; for analysis of magnetic storms on a monthly basis, the total number of storms per month was used. Yearly geomagnetic variation was represented by the mean of the *aa* and sunspot indices aggregated on a yearly basis, and the yearly incidence of magnetic storms. On the hypothesis that magnitude rather than (or in addition to) the frequency of occurrence might have significance, the total number of storms, the total number rated above 100 on the *k*-index, and the total number rated above 200 on the *k*-index, were employed.[19]

Uncertainties in the data. Sunspot numbers are adduced visually, and few sun-spots are associated with disruptions in the Earth's magnetic environment. Sunspots may, therefore, serve to indicate a general trend in geomagnetic activity, but do little to provide information on specific events within the earth's magnetic field. Additionally, the *aa*-index is a global, smoothed average of the strength of the planetary magnetic field. The actual geomagnetic environment present at any given location may vary; the *aa*-index can only approximate the field present at any given location. If behavioral disturbances are linked to disturbances in the geomagnetic field, such an association may be more visible with the incidence of magnetic storms, since of all independent variables this perhaps best reflects transient alterations in the geomagnetic environment. By contrast, since sunspot numbers have the most tenuous relationship with geomagnetic variation, they should demonstrate the weakest correlation.

The Dependent Variables

Two separate measures were employed: first, the monthly percentage of the annual totals of murder/non-negligent manslaughter and aggravated assault[20,21] (a more direct measure, the actual number of such offenses on a monthly basis, was not available); second, the annual totals of these categories of violent crime.[22]

Use of both variables was essential to a full understanding of any relationship present. While monthly data might yield a more precise understanding of any correlation between the geomagnetic field and behavior, if, as the model suggests, annual totals are inflated — i.e., increasing geomagnetic activity over the solar cycle yields increasing criminality — what may in fact be high values would not appear significant when considered as a percentage of yearly totals. Inclusion of analysis on a yearly basis should compensate for this. Examination of the raw data showed that the incidence of murder/non-negligent manslaughter exhibited a strong seasonal periodicity absent in aggravated assault; it was therefore necessary to consider them separately.

The Models

Data for monthly analysis was taken over the 10 year period from 1976 to 1986, to capture the entirety of cycle 21. This solar cycle is the third highest on record;[23] the years 1976-78 represent the onset, 1979-83 the peak, and 1984-86 the following trough. Data for yearly analysis was taken from the years 1957-1986, including the entirety of solar cycles 19,[24] 20 and 21. Two separate series of regressions were be considered:

Monthly variation: monthly variation in criminal behavior was regarded as a function of monthly variation in the magnetic environment. Two models were used:

I. Monthly Murder/Manslaughter

$$\text{Monthly Murder/Manslaughter} = b_0 + b_1\text{AA index} + b_2\text{Sunspot index} + b_3Z1 + b_4Z2 + b_5Z3 + b_6Z4 + b_7Z5 + b_8Z6 + b_9Z7 + b_{10}Z8 + b_{11}Z9 + b_{12}Z10 + b_{13}Z11 + b_{14}\text{Mag storm index} + b_{15}\text{Time} + \text{error}$$

II. Monthly Aggravated Assault

$$\text{Monthly Aggravated Assault} = b_0 + b_1\text{AA index} + b_2\text{sunspot index} + b_3Z1 + b_4Z2 + b_5Z3 + b_6Z4 + b_7Z5 + b_8Z6 + b_9Z7 + b_{10}Z8 + b_{11}Z9 + b_{12}Z10 + b_{13}Z11 + b_{14}\text{Mag storm index} + b_{15}\text{Time} + \text{error}$$

Figure 1. Model Equations

The monthly percentage of aggravated assault and murder/non-negligent manslaughter is a function of the *aa*-index, sunspot activity and a series of dummy variables designed to capture monthly variation due to seasonal changes (with December as the reference class).

Since data for the period under analysis are the percentage of annual totals of crimes (and not raw numbers of incidents themselves), it was assumed that population effects — increasing crime due to increasing population — would not be present; therefore, population was not included in the models examining monthly-level data.

Yearly variation: yearly variation in the incidence of such behavior was regarded as a function of a long-term but well-defined variation in magnetic activity. Due to the small number of observations (n=30), the study adjusted for population effects by regarding murder/non-negligent manslaughter and aggravated assault as a percentage of population; separate regression models were used for both the *aa*, magnetic storm and sunspot indices.

Murder/non-negligent manslaughter

III.	AA/Population	$= b_0 + b_1$AA index $+ b_2$Time $+ E$
IV.	AA/Population	$= b_0 + b_1$Sunspot index $+ b_2$Time $+ E$
V.	AA/Population	$= b_0 + b_1$Mag storm index $+ b_2$Time $+ E$

Note: Identical designs were used for models Va, Vb and Vc (i.e., the number of storms, the number of storms above k=100 and the number above k=200).

Aggravated assault

VI.	MNM/Population	$= b_0 + b_1$AA index $+ b_2$Time $+ E$
VII.	MNM/Population	$= b_0 + b_1$Sunspot index $+ b_2$Time $+ E$
VIII.	MNM/Population	$= b_0 + b_1$Mag storm index $+ b_2$Time $+ E$

Note: Identical designs were used for models VIIIa, VIIIb and VIIIc (i.e., the number of storms, the number of storms above k=100 and the number above k=200).

Figure 2. Regression Model Equations

"MNM" and "AA" (the annual incidence of murder/non-negligent manslaughter and aggravated assault, respectively) are functions of a counting variable, time, and the annual *aa*-index, annual mean sunspot numbers and the annual magnetic storm indices, respectively.

SUMMARY OF FINDINGS

Monthly Data

Regressions were run using the OLS method on each of the models described above. Results are summarized in the accompanying table (Table 1). None of the variables of interest (the *aa*-index, the sunspot index or the magnetic storm index) were significant in either model. In model I, the intercept (the value for December, the reference class) was most significant (t= 32.48), and many of the other dummy variables were also highly significant, indicating as expected that seasonal variation has the highest explanatory power in the model. Multicollinearity diagnostics were performed to detect the presence of covariance; the condition number fell within the indeterminant range where the presence of multicollinearity is neither confirmed nor rejected.

Table 1

MONTHLY DATA

Model/			After Autoregression		
Variable	MSE	|t|-statistic	Durbin-Watson	|t|-statistic	MSE
Model I	0.376		1.21		0.122
aa-index		0.615		0.813	
sunspots		0.370		0.215	
time		0.392		0.266	
mag storm	0.138		0.326		
Model II	0.089		1.13		0.073
aa-index		1.220		0.883	
sunspots		1.109		0.065	
time		0.932		0.015	
mag storm	0.861		1.167		

Note: Only the variables of interest are shown; t-statistics for the dummy variables were not included.

Since time series data were involved, tests for serial correlation were performed to detect the presence of autocorrelated errors; the existence of first and higher order autocorrelation was implied. Autoregressive processes were then estimated, but only the estimate of first order autocorrelation was statistically significant, suggesting that the original OLS results were distorted by first order serial correlation only. Autoreggressive procedures (with lag=1) were then performed. The statistical significance of many of the independent variables increased; however, the overall pattern of the results remained constant.[25] One unexpected result was the discovery of an unusual monthly variation. While it is commonly asserted that the incidence of crime increases during the summer months, the results indicate that the summer months will in general be associated with a lower incidence of such crimes than December (the suppressed class).[26]

Model II was analyzed in an identical manner; collinearity diagnostics again fell within the indeterminant range and, since the presence of serial correlation was suggested, autoregressive procedures were again implemented. After autoregression, none of the variables of interest approached statistical significance.[27] Once again, the dummy variables accounting for monthly variation were all significant; in this instance, however, they displayed the expected seasonal variation (i.e., an increase in assaults during the summer months).

Yearly Data

Regressions were run using the OLS method on each of the models described above; results are summarized in the accompanying table (Table II). The presence of multicollinearity was not suggested in any of the models; autoregressive procedures were implemented in each of the models.[28-33] The counting variable, time, was highly significant in all of the models employed. The *aa*-index was not found to be significantly explanatory for either aggravated assault or murder/non-negligent manslaughter. None of the magnetic storm variables (i.e., the total number of storms, the number above 100, and the number above 200) were significant, though the number above 200 approached statistical significance, with t= 1.942. Interestingly, the sunspot index *was* found to be significant for both aggravated assault (t=2.078) and murder/non-negligent manslaughter (t=2.296).[34]

Table II

YEARLY DATA

Model/ Variable	MSE	|t|-statistic	Durbin-Watson	After Autoregression |t|-statistic	After Autoregression MSE
Model III	0.0001		0.18		0.000021
aa index		0.397		0.297	
time		8.162		2.872	
Model IV	0.0001		0.16		0.000018
sunspots		1.461		2.299	
time		8.566		3.529	
Model Va	0.0129		0.82		0.00837
mag storm		1.253		0.544	
time		40.40		17.50	
Model Vb	0.0120		0.83		0.0083
mag storm 100		1.884		0.833	
time		39.067		20.01	
Model Vc	0.0119		0.71		0.0074
mag storm 200		1.984		1.916	
time		41.29		19.42	
Model VI	0.0126		0.78		0.0084
aa index		1.501		0.315	
time		40.81		19.34	
Model VII	0.0099		0.83		0.0074
sunspots		3.211		2.063	
time		45.50		22.52	
Model VIIIa	0.0001		0.18		0.00002
mag storm		0.035		0.003	
time		8.145		2.258	
Model VIIIb	0.0001		0.18		0.00002
mag storm 100		0.196		0.038	
time		7.407		2.828	
Model VIIIc	0.0001		0.2		0.00002
mag storm 200		0.357		0.620	
time		7.854		2.836	

DISCUSSION

Strong variation present in the raw *aa* and sunspot indices at both the weekly, daily and hourly level is lost when analysis is at the monthly level. This problem is aggravated by the smoothed nature of the *aa*-index itself. Thus, absence of correlation between either the *aa* or sunspot indices and monthly violent crime is not unexpected. The success of the studies cited at the outset indicates that the correlation might be improved by using more temporally precise data; however, such data is not available on a nationwide basis which, by default, would limit such studies to a specific geographic locale (wherein data could be made available from local police departments).

It is noteworthy, however, that a correlation between sunspots and violent crime was found in analysis on a yearly level. Initially this seems counterintuitive; if we assume that a possible correlation was camouflaged at the monthly level, why was this not even less evident when analyzed on a yearly basis? One explanation is that seasonal effects were so great that other relationships were obscured, which points to an inherent limitation of the model itself.[35]

Significantly, while the sunspot index is often associated with solar magnetic activity, it is not a direct measure thereof. The fact that more direct measures such as the incidence of magnetic storms evidenced no relationship whatsoever while the sunspot index demonstrated such a correlation is striking. This finding was totally unexpected, and runs counter to the generally accepted hypothesis that solar activity is associated with human behavior through its effect on the geomagnetic field.

Several possibilities arise. The presently available indices of geomagnetic activity may not reflect the actual solar parameter that is responsible, which might imply the existence of an energetic factor associated with solar activity, other than its magnetic component, that has an effect on human behavior. An alternative hypothesis is that the relationship may rest on a linkage between solar activity and some geophysical variable other than the magnetic field.

The significance of the counting variable, time, in each of the yearly models indicates that the data still display a time trend even after population effects have been taken into account, which is especially evident in the case of aggravated assault. This indicates that crime as a percentage of total population is on the increase over the thirty year period studied, a not unexpected result. The presence of the unexpected seasonal variation in the monthly data for murder (wherein the incidence of murder and non-negligent manslaughter *decreases* over the summer months) is intriguing; however, no explanatory hypothesis suggests itself.

CONCLUSION

This study failed to detect any relationship between the incidence of violent crime and direct indices of geomagnetic field activity. However, the significance of the sunspot index in the yearly models may hold some importance for the explanation of violent crime and other behavioral abnormalities. More importantly, the mild explanatory power of the sunspot index, contrasted with the lack of correlation between the dependent variables and any independent variable more directly associated with geomagnetic activity, suggests that additional research should concentrate on further examination of the possible existence of a non-magnetic solar effect on human behavior.

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REFERENCES AND NOTES

1. See here: H. Zirin, *Astrophysics of the Sun* (Cambridge University Press, Cambridge, NY, 1988).
2. T. Düll, and B. Düll, *Deutsch Med Wschr* 6, :95 (1935).
3. H. Friedman, et al, Psychiatric Ward Behavior and Geophysical Parameters, *Nature* 205, 1050 (1965).
4. H. Friedman, et al, Geomagnetic Parameters and Psychiatric Hospital Admissions, *Nature* 200, 626 (1963).
5. See here: F. Brown, In *American Scientist* 60, 756 (1972); R. Wever, In *ELF and VLF Electromagnetic Field Effects* (Persinger, Ed., New York, Plenum, 1974); and V.L. Bliss and F.H. Heppner, Circadian Activity Rhythm Influenced by Near Zero Magnetic Field, *Nature* 261, 41 (1976).
6. See here: W.T. Keeton, In *Proc. National Academy of Sciences* 68, 102 (1971); R.R. Baker, Human Magnetoreception for Navigation, In *Electromagnetic Fields and Neurobehavioral Function* (M.E. O'Connor and R.H. Lovely, Eds., Alan R. Liss, New York, NY, 1988).

7. R. Blakemore, Magnetotactic Bacteria, *Science* 190, 377 (1975); R. Beason and J. Nichols, Magnetic Orientation and Magnetically Sensitive Material in a Transequatorial Migratory Bird, *Nature* 309, 151 (1984); M. Walker, *et al*, A Candidate Magnetic Sense Organ in the Yellowfin Tuna, *Thunnus albacares*, *Science* 224, 751 (1984).
8. J. Olcese, *et al*, Evidence for the involvement of the visual system in mediating magnetic field effects on pineal melatonin synthesis in rats, *Brain Research* 333, 382-84 (1985); S. Reuss and J. Olcese, Magnetic Field Effects on the Rat Pineal Gland: Role of Retinal Activation by Light, *Neuroscience Letters* 64, 97-101 (1986).
9. J.P. Preslock, The Pineal Gland: Basic Implications and Clinical Correlations, *Endocrine Reviews* 5, 282 (1984).
10. P.M. Balaban, *et al*, Influence of a Stationary Magnetic Field on Bioelectric Properties of Snail Neurons, *Bioelectromagnetics* 11, 13 (1990).
11. See: *Modern Bioelectricity* (A.A. Marino, Ed., Marcel Dekkeer, New York, NY, 1988); M.E. O'Connor and R.H. Lovely, E*valuation of the Potential Carcinogenicity of Electromagnetic Fields* U.S.E.P.A., EPA/600/6-90/005A, June (1990).
12. A.L. Leiber and C.R. Sherin, Homicides and the Lunar Cycle, *American Journal of Psychiatry* 129:69 (1972); the cycle affects the earth's magnetic field at both the new moon and the full moon. Elevations in the incidence of homicide coincided with both phases over a 15 year period.
13. Alex D. Pokorny and J. Jachimczyk, The Questionable Relationship between Homicides and the Lunar Cycle, *American Journal of Psychiatry* 131, 827-29 (1974).
14. J. Tasso and E. Miller, The Effects of the Full Moon on Human Behavior, *Journal of Psychology* 93, 81-83 (1976).
15. Alex D. Pokorny and Roy Mefferd, Geomagnetic Fluctuations and Disturbed Behavior, *Journal of Nervous and Mental Disease* 143, 140-51 (1966).
16. NOAA, *Solar Geophysical Data: Prompt Reports* 525, 1 May (1988), p. 15.
17. NOAA, *Solar Geophysical Data: Prompt Reports* 526, 1 June (1988), p. 108.
18. J.H. Alle and E.A. Kihn, *Major Magnetic Storms* NOAA/NGDC, E/GC2, Boulder, CO 80303 (1990).
19. Such analysis was impossible using monthly level data since the incidence of storms above 100 on the *k*-index is comparatively low.
20. Federal Bureau of Investigation, *Uniform Crime Reports for the United States*, data has been taken from the 1982 and 1986 editions. While the use of percentages has limitations, it nonetheless should provide an indication of any relationship between an unusual magnetic event and the corresponding monthly percentage; eg., if a magnetic storm of unusual intensity took place, based on the model one would expect a correspondingly higher incidence of crime during that month than those months preceding or following the event.
21. Note that data was unavailable for the years 1976-77; as a result, these have been excluded from analysis.
22. Federal Bureau of Investigation, *Uniform Crime Reports for the United States*, 1982 and 1986 editions. Note that this data represents actual incidents, not percentages of annual totals.
23. The first highest was 1954-1965, the second 1987 to present (not yet complete).
24. Note that the data for cycle 19 is not complete; owing to changes in the reporting methods used by the FBI, data for the years 1955-56 was not comparable to later years, and was therefore excluded from analysis.
25. The model after autocorrelation (model I): ^y = 9.07 + (-0.005)aa index + (0.0003)sunspot index + (0.0007)time + (0.925)Z1 + (-1.46)Z2 + (-0.883)Z3 + (1.188)Z4 + (-0.843)Z5 + (-0.898)Z6 + (0.038)Z7 + (0.011)Z8 + (-0.372)Z9 + (0.602)Z10 + (-0.850)Z11 + (-0.006)mag storm index + e.

26. Eg., June was associated with a -0.90 percent decrease in the incidence of such crimes when compared with December (it must be remembered that the dependent variable in this instance is not the actual incidence of crime, but rather the monthly percentages of the annual totals of murder and non-negligent manslaughter).
27. The model after autocorrelation (model II): ^y = 7.8 + (-0.004)aa index + (0.00007)sunspot index + (-0.00003)time + (-0.609)Z1 + (-0.959)Z2 + (0.158)Z3 + (0.287)Z4 + (1.069)Z5 + (1.396)Z6 + (1.95)Z7 + (1.827)Z8 + (1.122)Z9 + (0.87)Z10 + (-0.02)Z11 + (0.0196)mag storm index + e.
28. Model III: ^y = 0.330 + (0.0013)aa index + (0.097)time + e. (These and all subsequent values are after autocorrelation.)
29. Model IV: ^y = 0.233 + (001)sunspot index + (0.0996)time + e.
30. Model Va,Vb,Vc: y = 0.39 + (-0.001)mag storm index + (0.097)time + e; y= 0.331 + (0.006)mag storm 100 + (0.098)time + e; y = 0.341 + (0.038)mag storm 200 + (0.097)time + e.
31. Model VI: ^y = 0.046 + (0.00006)aa index + (0.001)time + e.
32. Model VII: ^y = 0.037 + (0.000063)sunspot index + (0.0017)time +e.
33. Model VIIIa, VIIIb, VIIIc: y = 0.047 +(-3.28)mag storm index+ (0.001)time + e; y = 0.047 + (0.00001)mag storm 100 + (0.001)time + e; y = 0.047 + (0.00059)mag storm 200 + (0.0014)time + e.
34. The impact of the sunspot index on crime is, however, slight. The parameter estimate for the sunspot variable in model IV (murder/non-negligent manslaughter) is very small — each one unit increment in the sunspot index will lead to a 0.000063 increment in the dependent variable; the parameter estimate for this variable in model VII (aggravated assault) is similarly small, 0.001.
35. It should be remembered that the annual cyclical effect is hidden by seasonal variation in monthly data, since the data involved were not capable of evincing this effect— monthly models used *percentages of yearly totals*, not the actual number of crimes committed, eliminating the possibility of long-term trends involving overall increases or decreases on a yearly basis influencing the model. Analysis was, instead, focused on the relative distribution of activity within a given year.