pated in the absence of the smoking and illness link, especially with the increase in smoking by women. At some point diffusion per se would have ceased. Thus this model should not be interpreted as applying to the 21st century.

10. H. Lyon and M. Spruill, "A temporal cross-section analysis of cigarette price elasticity in the United States" (working paper 1977-5, Univ. of Houston, College of Business Administration, Houston, Tex., 1977). Price elasticity of demand is a measure of the responsiveness of quantity demanded to changes in price. It is defined as the percentage change in quantity divided by the percentage change in price.
11. D. Coate and E. Lewit, "The potential for reducing cigarette smoking through the use of excise taxes" (working paper, College of Medicine and Dentistry of New Jersey, Newark, 1980); J. Hadley, "A microeconometric analysis of smoking status and the demand for cigarettes" (working paper 1225-3, Urban Institute, Washington, D.C., 1979). A significant problem in cross-sectional analyses is accounting for interstate bootlegging (*12*).
12. *Cigarette Bootlegging: A State and Federal Responsibility* (Advisory Commission on Intergovernmental Relations, Washington, D.C., 1977).
13. Public Health Service, *Use of Tobacco: Practices, Attitudes, Knowledge, and Beliefs, United States—Fall 1964 and Spring 1966* (Government Printing Office, Washington, D.C., 1969); *Adult Use of Tobacco—1970* (Center for Disease Control, Atlanta, Ga., 1973); *Adult Use of Tobacco—1975* (Center for Disease Control, Atlanta, Ga., 1976). Some of the recent behavioral change may result as much from a general concern for fitness as from a specific response to smoking-and-health publicity.
14. The curtailment of excise tax growth partly reflects concerns about bootlegging (*12*).
15. The method used differs from and produced slightly more conservative estimates than that in my earlier study (*3*). Still more conservative estimates result if a logistic specification is substituted for the linear model.
16. Other behavioral changes are of much greater magnitude, and possibly health significance, than decreases in the numbers of cigarettes smoked. For example, sales-weighted tar and nicotine per cigarette have fallen by 50 percent since the 1950's. While the health implications of this change are unestablished, there is histologic evidence that the change may result in significantly decreased damage to health [O. Auerbach, E. Hammond, L. Garfinkel, *N. Engl. J. Med.* **300**, 381 (1979)].
17. I thank J. Flora, J. Hadley, J. Harris, M. A. H. Russell, M. A. Schork, and L. Young for helpful comments on the manuscript and F. Delman and M. Bloom for data on state laws. The findings were presented at the Fourth World Conference on Smoking and Health, Stockholm, Sweden, from 18 to 21 June 1979. Supported in part by grant HS 03634 from the National Center for Health Services Research.

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Solar Wind Data and Ionospheric Potential

In their article on "Solar wind control of the earth's electric field" Markson and Muir (*1*) correctly indicate that Barouch and Burlaga (*2*) associated rapid increases in solar wind velocity with decreases of the galactic cosmic-ray intensity. However, we did not claim to find any association between the value of the solar wind velocity and the cosmic-ray intensity. Indeed, our figure 8 (*2*) shows that, for the period we considered, this association could not easily be established. Our interpretation was that magnetic blobs are formed at the head of interplanetary streams, where the faster plasma catches up with the slower, earlier ejected, plasma.

If a relation between ionospheric electricity and cosmic-ray ionization of the upper atmosphere is sought, it seems that a direct approach should be investigated. Several cosmic-ray groups routinely fly balloons directly measuring the intensity of secondary particles as a function of altitude; this is probably the most straightforward way. Failing access to these data, one could look at the hourly values of the neutron monitor cosmic-ray detectors, or of cosmic-ray detectors aboard earth-orbiting satellites, which are published monthly in *Solar Geophysical Data* and are available on request from the World Data Centers. The indirect and somewhat unreliable associations between value of solar wind velocity and solar wind velocity changes, solar wind velocity changes and magnetic field enhancements (blobs), blobs and Forbush decreases and, Forbush decreases and upper atmospheric ionization form a chain where many unexpected other phenomena can distort the meaning of the numerical correlation that can be calculated.

A quick check of the daily averaged data presented by Markson and Muir in their table 1 is instructive in this respect [this time scale is more appropriate than hourly values, since the correlation time of the solar wind velocity is about 3 days (*3, 4*)]. These values were divided into three classes: those approximately coincident in time with the head of an interplanetary stream, those approximately coincident in time with the tail of an interplanetary stream, and those where the interplanetary data were too scarce or complex to be classified.

For the first two classes (six and seven points, respectively) the averages of the potentials given by Markson and Muir are 197 ± 14 and 224 ± 23 kV. Clearly, the statistics are as yet insufficient for definitive conclusions to be drawn from these data, although the ratio between these values is in the direction predicted by Markson and Muir.

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2 July 1980

The suggestion for a direct comparison between cosmic radiation data and ionospheric potential (V_I) variations is appropriate since in the referenced article (*1*) this relationship was deduced from inverse correlations between (i) solar wind velocity and V_I and (ii) solar wind velocity and cosmic radiation. I recently completed a study of cosmic rays and V_I and found the expected direct correlation. (Ionospheric potential is a measure of the earth's overall fair-weather electric field intensity.) The slope of the regression line is such that a 10 percent change in cosmic-ray flux measured by a neutron monitor corresponds to an approximately 15 percent change in the earth's electric field intensity.

This analysis was not performed earlier because not all the desired data had been acquired and we did not wish to delay publication of the finding that solar wind velocity controlled a fundamental property of the upper and lower atmosphere. In statistical studies of sun-weather relations, use of the solar wind velocity, a continuous property of the interplanetary medium, offers a considerable advantage over use of crossings of solar magnetic sectors as timing marks; the latter are nonparametric events which occur only two to four times a month.

A comprehensive examination of cosmic radiation data and V_I variations has now been completed through analysis of two independent V_I data sets: (i) the Bahamas measurements used in the solar wind analysis (*1*) and (ii) a recently acquired listing of German soundings provided by R. Mühleisen and H.-J. Fischer (Astronomisches Institut der Universität Tübingen). The Bahamas aircraft soundings (N = 92 for the purpose of analysis) were made during a 3-month period (December 1971 to March 1972), and the German balloon data (N = 237 for analysis) were obtained over a 17-year period (1959 to 1976). These are the only V_I data sets that are sufficiently extensive and coherent for the required analysis.

Balloon measurements of stratospheric ionization have not been conducted with sufficient frequency to allow meaningful comparison with V_I soundings, which have also been obtained sporadically. However, as noted by Barouch, the required unbroken time series of cosmic radiation measurements from satellites and neutron monitors exist; these have been correlated with both sets of V_I data. The satellite measurements used are from IMP-4 during the period June 1969 to December 1972; they provide the longest coherent satellite data set available covering the period of the Bahamas records. The Mount Washington neutron

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Table 1. Summary of correlations between V_I data separated into groups at least 2 days apart and corresponding cosmic radiation.

Data sources	Results		
V_I/cosmic rays	r	N	P
Bahamas/satellite	.663	11	<.05
Bahamas/Mount Washington	.486	15	<.05
Germany/satellite	.367	52	<.01
Germany/Mount Washington	.402	151	<.0001

monitor records were also analyzed; they provide a ground-level measure of secondary cosmic radiation going back to 1954.

Barouch mentions the problem of independence in analysis of solar wind data and states that daily averages provide about the right time scale. Analysis of the daily averages of the Bahamas V_I data versus the corresponding satellite cosmic-ray daily averages gave a correlation coefficient $r = .705$, $N = 20$, $P < .001$. To further ensure data independence without reducing the number of points too severely, all V_I data were separated into groups that were at least 2 days apart (generally longer) and averaged. Table 1 summarizes the results of correlating the grouped V_I averages versus the corresponding grouped cosmic radiation averages. In all cases the correlations are positive and significant at or beyond the 5 percent level.

To verify that V_I is predominantly controlled by changes in ionizing radiation compared to upper atmosphere generators, the Bahamas V_I data were correlated with both the B_z component of the interplanetary magnetic field and the AE geomagnetic index. The former is highly correlated with magnetospheric-ionospheric electric fields, while the latter is a good measure of the auroral electrojet, which is maintained by the magnetospheric-ionospheric generator. Both B_z and the AE index were uncorrelated with V_I.

The significance of these results is that we can gain insight regarding the mechanism: for the earth's electric field to increase with greater atmospheric ionization, the effect must be due to larger currents from existing thunderstorms plus possibly positive feedback in the form of increased thundercloud electrification. The effect cannot be due to enhanced ionization in the fair-weather portion of the global electrical circuit because this would partially short out V_I, causing it to become smaller. These findings are in agreement with a proposed mechanism by which solar variability can modulate atmospheric electrification (*2*).

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References and Notes

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3. Details of the V_I/cosmic-ray study were presented at the 6th International Conference on Atmospheric Electricity, July 1980.

1 December 1980

Wavelength-Dependent Enhancement in Brain and Behavior

Gouras and Zrenner have reported that wavelength-dependent latency differences cause color-opponent ganglion cells in the monkey retina to exhibit a wavelength-dependent response enhancement when the frequency of a flickering light is varied (*1*). Their single-cell results correspond to the wavelength-dependent enhancement found when human observers are asked to judge the brightness of intermittent lights (*2-4*). The psychobiological correspondence can best be examined if Gouras and Zrenner's data are replotted in the same form as the most complete behavioral results. Figure 1A shows the enhancement exhibited by Gouras and Zrenner's nine red-green cells. Two peaks occur—a large one near 550 nm and a small one near 435 nm. Figure 1B shows the results from Wasserman's single-flash behavioral study, which found three peaks (*3*). The middle peak in the behavioral data would be expected to correspond with a peak in Gouras and Zrenner's yellow-blue cells. Those data were not reported although their reference 6 leads one to expect that their yellow-blue cells did exhibit a third peak. Figure 1C shows the results of Ball's multiple-flash behavioral study (*4*). He also found wavelength-dependent enhancement peaks, although the two shorter wavelength peaks fused. Two peaks at shorter wavelengths were resolved by Ball when the observer was chromatically adapted to 540 nm.

Even though the size and locations of the peaks vary, the psychobiological correspondence is clearly very good. But certain problems still remain. (i) Gouras and Zrenner's data seem to indicate that

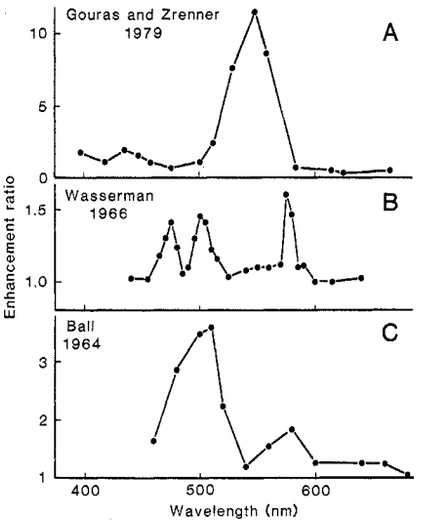

Fig. 1. (A) Gouras and Zrenner's single-cell data replotted. The enhancement ratio was calculated from the different sensitivities to low and high flicker rates [figure 1B in (*1*)]. (B) Wasserman's behavioral results [figure 3 in (*3*)]. (C) Ball's behavioral data [figure 5 in (*4*)]. The enhancement ratio was calculated relative to the Talbot level.

the enhancement increases as the flicker frequency is raised from about 1 Hz to about 15 Hz and then declines only slightly at 33 Hz. But the behavioral results, as well as earlier single-cell research conducted with white lights (*5*), would have led one to expect a much greater decline at high frequencies. (ii) Although many behavioral investigations (*2-4*) found wavelength-dependent enhancement effects, other studies (*6*) found that enhancement was independent of wavelength. Therefore, the major current problem in this area is to account for the two different outcomes. One possible hypothesis would be that a wavelength-independent enhancement effect occurs in the achromatic cells in addition to the wavelength-dependent effect in the chromatic cells. Since the relative contribution of the two cell types varies as a function of stimulus size and intensity as well as light adaptation (*7*), one would then expect that studies done under conditions favoring the achromatic cells would tend to show wavelength independence while studies done under conditions favoring the chromatic cells would tend to show wavelength dependence. Gouras and Zrenner may have data that would contribute to the resolution of these questions. If so, the presentation of these data would be very valuable.

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