A Possible Mechanism for the Production of Sun-Weather Correlations

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ABSTRACT

If, as has been alleged, variations in the outflow of solar plasma have some effect on our weather, then the relevant coupling mechanism must be sought. It is suggested here that planetary waves, which may be subjected to variable reflection in the upper atmosphere and so may induce variable interference patterns in the lower atmosphere, constitute a potential candidate.

Numerous attempts have been made to establish that a correlation exists between some parameter describing the conventional meteorological domain of the atmosphere (as distinct from the ionospheric domain) and some parameter representative of disturbed conditions on the sun. Most such attempts have proven to be failures. Exceptions have been reported, but they have employed as their supposedly solar parameter a geomagnetic fluctuation index that, though strongly correlated with solar disturbances, necessarily contains as well a meteorologically induced component. Their relevance to what may briefly be termed "sun-weather correlations" is therefore open to serious doubts.

My own skepticism in this regard has been expressed elsewhere (Hines, 1973). It is not in the least undermined by the "reply" (Shapiro, 1973) it was given, since that reply contained nothing that I would not have conceded at the outset—in particular, the existence of a strong correlation between two distinct magnetic indices, which I at no time questioned—and it contained nothing that argued against the actual points I was making, which were concerned with the role that could be played by the relatively low-intensity meteorologically induced component of such indices in statistical correlations that did not take the trouble to eliminate that component. On the contrary, Fig. 4 of the "reply" in fact provides the basis for a minor variant on my initial theme, since it establishes that abnormally low intensities of magnetic fluctuation (and hence, it might be supposed, abnormally low intensities of the meteorologically induced component of those fluctuations) are as much a part of the pattern of correlation with meteorological data as abnormally high intensities of magnetic fluctuation are said to be. Pending further statistical studies by myself or others designed to elucidate the potential role of meteorologically induced geomagnetic fluctuations, I remain a skeptic.

A new era in the study of sun-weather correlations has now been opened, however. It results from the introduction of an undoubtedly solar parameter—the solar magnetic sector structure—and from a claim for a correlation of this parameter with atmospheric vorticity at and near the 300-mb level (Wilcox *et al.*, 1973, 1974). Such skepticism as I might wish to express in connection with this claim would have to be based on its statistical significance, upon which I have yet to form any firm convictions. But in the absence of counterclaims, the new claim undoubtedly supports the contention that a sun-weather correlation exists and that a causal mechanism for it must be found.

Without in any way wishing to imply a prejudgment of the validity of this contention, I should like to suggest one possible mechanism that avoids some of the difficulties that have bedevilled other suggested mechanisms, though I wish at the same time to point out that the new mechanism carries with it its own set of difficulties.

The essential point to be made is that the meteorological systems in question can be analyzed as planetary waves, that these waves propagate their energy upward, that they can be reflected at higher elevations, and that they can then return their energy to lower levels and there interfere constructively or destructively with the initial systems that gave them their being. Indeed, in a steady-state situation (if one could ever be produced) the entire system would have to be treated as something of a leaky waveguide, with the pattern of meterological parameters at all elevations being determined, in part, by a vertical standing-wave component whose intensity would be dependent on the reflection and absorption introduced by overlying levels.

With these facts in mind, it becomes apparent that some change in the meteorological systems at low altitudes might be brought about by some change in the reflection or absorption of planetary waves at high altitudes, the latter change being introduced by some process that depends on solar disturbance. Strong aurorally associated heating of the lower thermosphere and strong winds engendered by that heating, or more directly and more intensely by the $\mathbf{J}\times\mathbf{B}$ force of auroral current systems, rank as possible processes.

Mechanisms that have been proposed in the past have tended to rely on some "triggering" process, whereby a small input of energy (or contaminant, or whatever) at high levels, of an intensity appropriate to the diminished gas concentration at those levels, manages to switch the lower levels of the atmosphere from one pattern of behavior to some other pattern of behavior, with a resultant output far out of proportion to the input. In the mechanism proposed here, the energy that is invoked to produce changes at meteorological altitudes actually originates in its required form at those altitudes, and might then be expected to be of an intensity that is matched to the requirements of those altitudes. This energy could be added anomalously by anomalously strong reflection or diminished absorption, or it could be reduced anomalously by anomalously weak reflection or enhanced absorption, or it could be simply altered in phase anomalously by an anomalous change in the height of reflection, and it would produce anomalous effects in each case. It would, moreover, have some geographic phase coherence with the systems it is being called upon to change, and it might then be expected to be more efficient in producing a change than an incoherent mechanism would be.

It has long been recognized, for example by Charney and Drazin (1961), that reflection and/or absorption of planetary-wave energy at high elevations must be strong, for otherwise that energy would heat the ionospheric regions far beyond anything that is observed. Charney and Drazin concluded, from an analysis of vertical propagation through horizontal background winds, that reflection at heights well below the ionosphere is indeed severe, particularly in summer and almost as effectively in winter, with perhaps an exception in very brief equinoctial conditions. Dickinson (1968), who allowed for latitudinal variations of background wind, confirmed their conclusion for summer conditions and inferred strong absorption in the middle atmosphere for low latitudes in winter, but found relatively free propagation to ionospheric altitudes for middle and high latitudes in winter. The mechanism proposed here might then be expected to be most relevant, if it is ever relevant, at middle and high latitudes in winter. It is for these latitudes, and only for this season, that Wilcox *et al.* (1973, 1974) claim a correlation with solar sector structure.

The proposed mechanism is not without its difficulties. Among the chief of these is the possibility of severe dissipation of planetary waves at altitudes so low that the original problem recurs in modified form: to find a mechanism whereby the reflection or absorption at those altitudes could be affected by solar disturbances. Newtonian cooling below the mesopause is expected to damp planetary waves severely at the equinoxes and to introduce an amplitude attenuation by at least a factor of 2 (for a one-way transit) in winter (Dickinson, 1969). Above the mesopause, if not below, attenuation by viscosity and thermal conduction becomes important (Hines, 1963). It would appear that, if for this reason alone, the reflection of planetary waves at some height below about 100 km must be susceptible of appreciable alteration at times of solar disturbance if the proposed mechanism is to be effective. The abnormal heating and abnormal winds that are associated with auroral currents may be effective for this purpose, though their most intense effects are to be found only at somewhat higher elevations. Those effects are, moreover, variable in latitude and longitude; if these variations persisted to the heights at which an altered reflection is to be invoked, they would tend to destroy the geographical phase coherence that was noted above. Further, it is by no means evident that the reported correlation has anything to do with the occurrence of aurora itself; some quite distinct intermediary might well be required.

These and other difficulties must limit any significance that might be attached to the planetary-wave mechanism. They can be circumvented by variants (e.g., gravity waves might be invoked to provide the coupling, and they need not be as susceptible to dissipation as the planetary waves are), but each variant adds its own assortment of problems and loses some of the intrinsic merit of a mechanism in which the basic meteorological system simply interferes with itself. The variants will therefore not be pursued here.

Indeed, the basic mechanism will be pursued no further either; at least, not here. Nor would I advocate attempts to establish its relevance (though I would advocate attempts to establish its irrelevance) prior to the establishment of further evidence, or even the further establishment of the present evidence, that a real correlation exists and must be explained.

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