matters arising

Solar modulation of atmospheric electrification and the Sun–weather relationship

MARKSON[1] has provided a useful summary of reasons for looking to atmospheric electrical structure for an explanation of 'Sun–weather' correlations, but the specific global and local mechanisms which he proposes do not, in the light of available evidence, apparently produce such effects frequently enough to explain the observations. Effects more directly related to magnetospheric and auroral phenomena would seem to show more promise in explaining the observed coupling of solar activity to lower atmosphere electrical phenomena.

The global effect proposed by Markson is that the 'Forbush decrease'[2] in cosmic ray intensity associated with solar flares results in a decrease of atmospheric ionisation with consequent effects on the 'global circuit'. Measurements made on a high mountain by Reiter[3] have shown that the fair-weather electric field and current show 10–30% effects related to solar magnetic sector boundary crossings. Forbush measured decreases of the order of 1% at low latitudes and even at higher altitudes and latitudes, the effects rarely exceed a few per cent.[4] As Markson points out atmospheric conductivity is expected to vary as the square root of the Forbush decrease, (ionisation rate) it is difficult to see how this mechanism could produce the observed effects, as decreases of the order of 50% in cosmic ray flux at low latitudes would be required.

The local effect proposed by Markson involves the direct penetration of ionising radiation effects to the tops of thunderclouds, (~20 km at mid and high latitudes). While this is perhaps possible in some rare solar proton (PCA) events[5], such as the large flare of August, 1972, there is little evidence that substantial conductivity variations occur as low as this after more modest events. Yet balloon measurements at high latitudes[6,7] typically show a 30% increase in the vertical field following geomagnetically disturbed periods. Thus it would seem that we must look for effects more directly related to magnetospheric and auroral processes to explain the reported data. One problem would seem to be Markson's acceptance of the "classical picture" of atmospheric electricity, where an "equipotential surface is considered to exist at about 60 km", which does not allow the penetration of higher altitude electrical effects. The earliest rocket-borne conductivity measurements in 1950 (ref. 8) showed that the classical exponential increase of conductivity did not persist above 40 km, a result attributed to aerosol particle layers which has since been frequently confirmed[9]. Mühleisen[7] has observed horizontal electric field gradients totalling ~100 kV between high and mid latitudes following magnetic disturbances, and Tyutin[10] in the USSR has reported a 'permanent' mesospheric vertical field of similar magnitude. (We have tentatively confirmed the USSR measurements and suggested that the 'shorting out' of the vertical field by ionisation produced by aurorally related radiation might produce local changes in the lower atmosphere vertical field and also the observed horizontal potential differences, by adding the permanent mesospheric potential to the lower atmosphere circuit at high latitudes[11].) These measurements clearly demonstrate the invalidity of the classical picture for studying many possible coupling mechanisms.

Other promising avenues of investigation would seem to be the direct 'mapping' of ionospheric fields to low altitudes[12] and of aurorally produced charge separation[13] inducing displacement currents and electric fields in the lower atmosphere. Magnetospheric and auroral phenomena would seem to have a chance of explaining the 22-yr 'magnetic cycle' Sun–weather effects cited by Markson, because of the likelihood that they could be influenced by the details of the solar magnetic field structure. An intermediate mesospheric coupling circuit modulating the lower atmosphere circuit would have the attractiveness of providing a mechanism responsive to auroral particles or bremsstrahlung rather than requiring rare high intensity events, and could thereby provide a more prevalent coupling effect due to the much greater frequency of such events.

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MARKSON REPLIES—Hale's objection may be summarised as: (1) he does not believe that the requisite changes in ionisation occur; nor (2) that the classical picture of atmospheric electricity is valid. He is inaccurate in his quotation and citation, and there is some question regarding his interpretation of data and their significance.

I wish to point out the following: conductivity variations occur sufficiently low in the atmosphere and frequently enough to be a significant factor in solar modulation of current flow in the global circuit. Hale refers to relatively small changes in the galactic component of cosmic radiation measured on the ground which are not representative of the much larger variations of ionising radiation in the lower stratosphere. Winckler[1]. in summarising his balloon program in which cosmic rays were measured at mid-latitude (Minneapolis) states "Probably the single most significant finding of the entire series (of flights) was the frequent occurrence of intense low energy cosmic rays. They originated from large solar flares but had energy spectrum so steep that the particles were not detected by the extensive network of sea-level cosmic ray monitors established during IGY. The particles were measured directly, however, by means of balloons at altitudes greater than 20 or 25 km". Not only are solar controlled changes in ion production larger and more frequent in the 20–30 km height range compared to near the Earth, they generally are of the opposite sense, increases instead of decreases[1–3]. Akasofu and Chapman[4] (Hale's reference) discuss three Forbush decreases in a 16-day period which resulted in a cumulative 20% reduction in cosmic ray rate at the

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