Thunder and electric storms

A neat measurement of the stratospheric electrostatic fields throws light on the link between solar activity and terrestrial climate.

CAREFUL readers of the scientific literature are forgivably suspicious of articles that refer to the very distant past. The sceptical will ask whether the authors of such an article have sinister motives for ignoring recent work, and will probably dismiss the possibility that they have managed to resuscitate an important problem whose trail runs cold before, say, 1980. So what is to be made of the contribution now published by R.H. Holzworth and T. Onsager of the University of Washington (Seattle) and P. Kintner and S. Powell of Cornell University to the problem of atmospheric electrostatic fields? Their paper (*Phys. Rev. Lett.* 53, 1398; 1984) manages one reference to a regular paper (by Holzworth) after 1980, but is mostly spattered with references dating from the 1920s and earlier.

Holzworth *et al.* have nevertheless managed to break new ground, and in a stimulating fashion. What they have done is to equip two balloons so as to measure the electrostatic field in the Earth's atmosphere at an altitude of 26 km. The balloons were released from New Zealand in March last year, and allowed to drift for two weeks eastwards across the Pacific at a latitude of 45°S. The lateral separation between the balloons was never less than 750 km. The objective was to compare the electric field strength at two such widely separate locations. The conclusion that the two records are very similar, but that fluctuations of field strength from day to day are much greater than expected, have an important bearing on the understanding of atmospheric electricity.

One of the obvious early references in Holzworth *et al.* is to C.T.R. Wilson, whose design of the closed chambers that became the workhorses of early cosmic-ray measurements was originally part of an investigation of atmospheric electricity. What Wilson knew was simple — that thunderstorms consistently carry positive electric current upwards in the atmosphere and that near the surface of the Earth, the electric field strength (the gradient of electric potential), while variable, can amount to several hundred volts per metre. Wilson had the wit to recognize that the cumulative effect of thunderstorms must be to some degree offset by a less spectacular but continuous downward electric current, for the electrical potential between the surface of the Earth (negatively charged) and a presumed upper conducting layer (the ionosphere) cannot

increase indefinitely.

But how can the atmosphere conduct electricity, even at the low rate suggested by the observations? Wilson was the first to show that the production of ions by cosmic rays is the essential mechanism for rendering the bulk of the atmosphere conducting. The potential difference between the surface of the Earth and the ionosphere is typically no more than some tens of thousands of volts — the large potential gradient near the surface quickly trails off with increasing altitude as cosmic-ray ionization increases the conductivity of the atmosphere — at 26 km Holzworth *et al.* measure fields of less than 1 V m⁻¹.

The immediate significance of the new balloon measurements is that they have demonstrated a technique for measuring electrostatic fields beneath the ionosphere that is bound to become established if sparsely used. From this first batch of data, the conductivity at 26 km seems virtually constant for days on end, while the electrostatic fields measured by the two balloons, even when separated by up to 3,000 km, are identical to within 10 per cent for most of the time (perhaps 70 per cent of the 16 days of common observation). That is understandable if, indeed, the field at 26 km can be likened to the electrostatic field between two parallel conducting plates, one the ionosphere and the other the ocean surface.

For then, given the high conductivity of the upper and lower surfaces, the relaxation of the distribution of charge must be rapid. The local effects of thunderstorms carrying positive charge into the stratosphere would be quickly dissipated. Holzworth *et al.* point out that there nevertheless seems to be a daily variation of field strength at 26 km, at least when 10-minute records for consecutive days are averaged together, with a possibly shallow maximum of field strength at 20h Universal Time. The records, however, show no drift in the timing of the diurnal variation with the eastward passage of the two balloons across the Pacific, which provisionally gives the lie to theories that the global pattern of the vertical electrostatic field is fixed in relation to the position of the land masses on the surface of the Earth.

The chief interest of these data, according to their authors, is the enormous variation in the pattern of the vertical electrostatic fields measured by each balloon on different days. Field strengths are generally less at local morning than

after noon, but otherwise the variability is so great that one day's record is unrecognizably different from the next's. The inference, which is important, is that there must be substantial fluctuations (perhaps by a factor of two) in the global vertical current in the atmosphere, and on time-scales of the order of 10 minutes, perhaps themselves the consequences of fluctuations of thunderstorm activity near the surface of the Earth.

While Holzworth (among others) has previously been responsible for vertical field measurements at altitudes up to 30 km, the twin balloon measurement seems to be the first of its kind. Evidently the conclusion that there are large short-term fluctuations of the global electrostatic field could not have been sustained by measurement with a single balloon (for local thunderstorms might always have been responsible). One obvious benefit that lies ahead is a more detailed correlation of the global field fluctuation with observed thunderstorm activity (presumably anywhere in the world). The point is obviously important because, while there seems little dispute about the correlation between thunderstorm activity and the strength of the electric field, the degree to which the former may be excited by the latter, involving as it does the non-linear dynamics of condensation in cumulus clouds, remains to be settled.

So does the possibility that the electrostatic field beneath the ionosphere may provide a physical link between sunspot activity and terrestrial climate. Ralph Markson has argued that solar activity, by affecting the cosmic-ray flux and thus the conductivity of the atmosphere, might influence the occurrence of thunderstorms (*Nature* 273, 103; 1978), but by a mechanism which has been disputed (L.C. Hale, *Nature* 278, 373; 1979) and which again hangs on the degree to which electric fields and thunderstorms are mutually stimulating.

Unfortunately, given the short-term global fluctuations of the vertical field, it is by no means clear how quickly careful monitoring of the electrostatic field by an *in situ* measurement will be feasible, and how quickly that will yield direct evidence bearing on the question whether solar activity and terrestrial weather are in any way linked by atmospheric electric fields. At least another sunspot cycle will go by before matters are cleared up.

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