Measurements of corona ion induced atmospheric electricity modification near to HV power lines.

J C Matthews, A J Buckley, P A Keitch, M D Wright and D L Henshaw
H H Wills Physics Laboratory, Tyndall Avenue, Bristol BS8 1TL, UK
J.C.Matthews@Bristol.ac.uk

Abstract. Corona ions emitted from high voltage power lines and propagated by the wind can attach at a given rate to atmospheric aerosols and will create disturbances in the Earth’s DC electric field. Local electric field variations have been measured using field meters upwind and downwind of power lines and a fixed site monitoring station has been built to enable space charge near a power line to be continuously recorded. At similar sites, the high resolution mobility spectra of atmospheric ions and charged small aerosols have been ascertained using two custom-built mobility spectrometers. These measurement techniques have indicated an increase in the charge state of small aerosols at ground level and an increase in space charge with high variability downwind of high voltage power lines.

1. Introduction
Air-borne ions have been postulated to mediate ill health effects [1], especially in the vicinity of high voltage (HV) power lines. This report outlines the ongoing work investigating the changes of atmospheric electricity caused by HV power lines, in particular, measuring the presence of ions and charged aerosols within a few hundred metres of HV lines.

A recent case-control study by Draper et al [2] investigated the association between distance of birth address from HV power lines and incidence of childhood leukaemia. It was found that there was a statistically significant 1.23-fold increase of risk for children born within 600 m from HV lines. An increase in risk beyond 200 m is beyond the range of the direct 50 Hz magnetic or electric fields. There is also a link between leukaemia and pollutants. Studies by Knox [3] have shown an increase in risk for childhood cancers, including leukaemia, near to sites of air-borne pollutants.

Fews et al. [4] proposed a mechanism whereby HV power lines could increase human exposure to airborne carcinogens by increasing their charge state. Power lines undergo corona discharge due to high electric field gradients existing around sharp points (e.g. water droplets, dirt) which are sufficient to produce localised ionisation of air. This process is affected by, amongst other things, weather conditions and the state of repair of the line, thus levels of corona may vary greatly.

Corona ions can escape and attach to ultrafine aerosols. In their natural charge state approximately 30 % of inhaled aerosols of size 200 nm are deposited in the lung. Adding charge to these aerosols is postulated to increase the deposition resulting in increased health risk due to image charge effects [5].

Following production, corona ions can be carried by a wind away from HV power lines largely in the form of separate unipolar clouds. These unipolar space charge clouds travel with the wind and are sufficient to produce local DC potential gradients measured from the ground. Space charge

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disturbances caused by ions produced by an HV power line have been previously measured as far as several km away [6]. Much work has been carried out on the production of corona and the 50 / 60 Hz fields near to power lines [7], but the investigation here looks at the effects at distances from the line beyond the direct field.

To evaluate the presence of charged particles in the air at distances beyond the direct electric and magnetic fields produced by HV power lines, atmospheric measurements are being made upwind and downwind of HV lines in the area surrounding Bristol, UK. Two measurement techniques are presented here; the measurement of space charge using ground based electric field meters and measurements of ground level small ions and small aerosol concentrations and mobilities.

2. Experimental techniques
On a clear dry day, the Earth has a quasi static potential gradient which provides an electric field of ~ 100 V m\(^{-1}\). Corona ions produced from an HV power line in a crosswind cause clouds of unipolar space charge to propagate hundreds of metres downwind of the line, this space charge modifies the electric field as measured from the ground and results in a distinctive rise and fall in field strength. These perturbations can be measured using ground based electric field meters.

JCI 140 field mill meters [8] mounted at 1 m height were used to measure the electric field above the ground at various HV power lines within a 30 mile radius of Bristol. The field meters were placed at measured distances upwind and downwind and set up at least 5 m from any object that would perturb the electric field, affecting the measurement. Data was recorded every second by a portable computer. The electric field mill meters have been designed to be immune to ion currents caused in ion rich environments by using phase sensitive detection, as described in IEEE guidelines [9].

Alongside these measurements, a fixed site monitoring station (FSMS) has been built to continuously monitor electric field perturbations at 175 m from a 400 kV power line in Littleton upon Severn, South Gloucestershire, UK. The FSMS consists of an all weather field mill meter (JCI 131), designed to work in precipitation, connected to a control box (JCI 234) which outputs voltages for data-logging [8]. Electric field data is recorded every second and the average weather conditions are recorded every 10 minutes.

Small-ion and small aerosol concentrations and mobility spectra in the diameter range 0.4 nm to ~30 nm were obtained using a custom-built aspiration condenser ion mobility spectrometer (ACIMS) [10]. Measurements were made simultaneously at known distances upwind and downwind of power lines in the Bristol area. Measurement of the full mobility spectrum takes approximately 15 minutes, with data from several measurements being combined prior to analysis to reduce noise and increase accuracy.

3. Results and discussion
Figure 1 shows the electric fields recorded at 1 second intervals approximately 230 and 80 m downwind and 150 m upwind of a 132 kV power line at Elberton, South Gloucestershire, UK on the 4\(^{th}\) May 2006. The weather was fine, there was no rain, and the wind direction was tangential to the line (westerly - the power line runs from SWW to NEE). The upwind time variant field is typical of the Earth’s natural electric field. Similar results have been found away from power lines in urban and rural settings. The downwind results are typical of other results found downwind from power lines within this investigation. The standard deviation of the trace does diminish in size with distance from the line. However, in previous studies, elevated levels of space charge have been found at distances of 7 km in the direction of the wind from a 400 kV power line in Lower Godney, North Somerset, UK. Spot measurements on 15\(^{th}\) March, 2000 (average wind speed, 3 m s\(^{-1}\)) recorded an average vertical electric field of 390 V m\(^{-1}\) downwind of the line whilst a background field level of 150 V m\(^{-1}\) was recorded upwind [11]. This and other results show an increase in the mean and standard deviation of electric field readings at various distances downwind from the line compared to upwind, indicating the possible presence and fluctuating nature of clouds of predominantly positive ions or charged...
Preliminary results from the FSMS frequently show distinctive fluctuating traces and, where corona ions are suggested to be present, the electric field is more changeable with changes of many tens of V m⁻¹ over a few seconds. The standard deviation of the electric field level is highest when the wind direction places the monitoring station downwind of the HV power line. Rates of change of electric field of up to 100 V m⁻¹ s⁻¹ have been seen on wet and windy days but whether this is concurrent with the onset of precipitation is still under investigation.

Figure 2 shows typical upwind and downwind mobility spectra measured near to a 275 kV line on a drizzly day with an average wind speed of 1.3 m s⁻¹. This result shows an increase in the number of positive aerosols (2 to 50 nm) downwind of the line. In this example there is a 17-fold increase in the number of positively charged small aerosols (size range 2 to 50 nm) downwind compared to upwind, and a 25-fold decrease in the number of negatively charged aerosols. This is consistent with the theory that the ions (in this example positively charged) are attaching to atmospheric aerosols, increasing the number and charge of positive aerosols and changing the charge state of the negatively charged aerosols to positive.

4. Conclusions

Data recorded by field meters downwind from power lines in a crosswind have shown an increase in mean electric field and an increase in standard deviation compared to measurements made upwind. This indicates that the space charge travels in clouds and reinforces results found by Fews, et al. [4] and other previous studies [7]. Measurements of perturbations of the Earth’s natural electric field many hundreds of metres from the power line indicate that corona ions may be present at distances from the line greater than that of the direct fields. Further work is required in other areas to determine whether there is a mechanistic link between these corona ions with an increase in childhood leukaemia. Further results from the FSMS and short measurements at various other sites will enable further assessment of corona ion production and propagation in all weather conditions.

Results from the ACIMS have shown an increase in charged small aerosols downwind from power lines, in most cases investigated in fair weather conditions the increase has been of positive ions.
Further work in this area will include more contemporaneous measurements upwind and downwind from power lines, and in urban and rural areas away from power lines. Contemporaneous measurements of electric field and ion concentrations will be made and comparisons and both sets of results will be compared.

**Figure 2** Typical power line ACIMS mobility spectra obtained from contemporaneous measurements (a) 330 m upwind and (b) 532 m downwind of a 275 kV line at Puxton, North Somerset on the 30th April 2004.

5. **Acknowledgements**

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