CHAPTER 7

RESULTS OF FAIR-WEATHER MEASUREMENTS

7.1 THE COLORADO MEASUREMENTS

The work presented in this chapter is based on atmospheric electric and meteorological data continuously recorded over a two year period using instrumentation and measuring methods descried in the previous chapters of this book. Evaluation of the data suggests that the fair-weather electric field is primarily generated by local electrostatic generators which all contribute to a larger global circuit. The main generating mechanism appears to be linked to convective mixing processes in the atmosphere. The amount of charge contributed to the global electric circuit by local thunderstorms could not be determined from the measurements. Since convective mixing is more dominant over land than sea one can expect a small global diurnal increase in the fairweather field produced by static electricity generated over land masses as the sun passes over different world continents. Such global variations were observed in Lappland by Simpson in 1905 and from ocean measurements by Hoffman in 1923. The diurnal variations of the fairweather electric field in Boulder is compared to Hoffman's ocean results.

The use of digital storage and evaluation technology has made it possible to study atmospheric electric phenomena in great detail. Meteorological and atmospheric electric parameters have been continuously monitored at Colutron Research in Boulder Colorado over several years. Boulder is located at latitude 40° N and longitude

105° W and at an altitude of about 1500 m above sea level. The different parameters recorded are electric field, air-earth current density, negative and positive ion concentrations, relative humidity, temperature, wind velocity, and barometric pressure. Readings are taken every 30 second and stored on magnetic disks. The measurements are performed at ground level. In this study only data from undisturbed fairweather days were selected, *i.e.* cloudless days without disturbances from frost, dew, blowing dust *etc.* The average of "hourly means" from any chosen number of fairweather days is examined for diurnal variation patterns. The curves in Fig. 49 show an example of electric measurements for sixteen fair-weather days in December 1990.

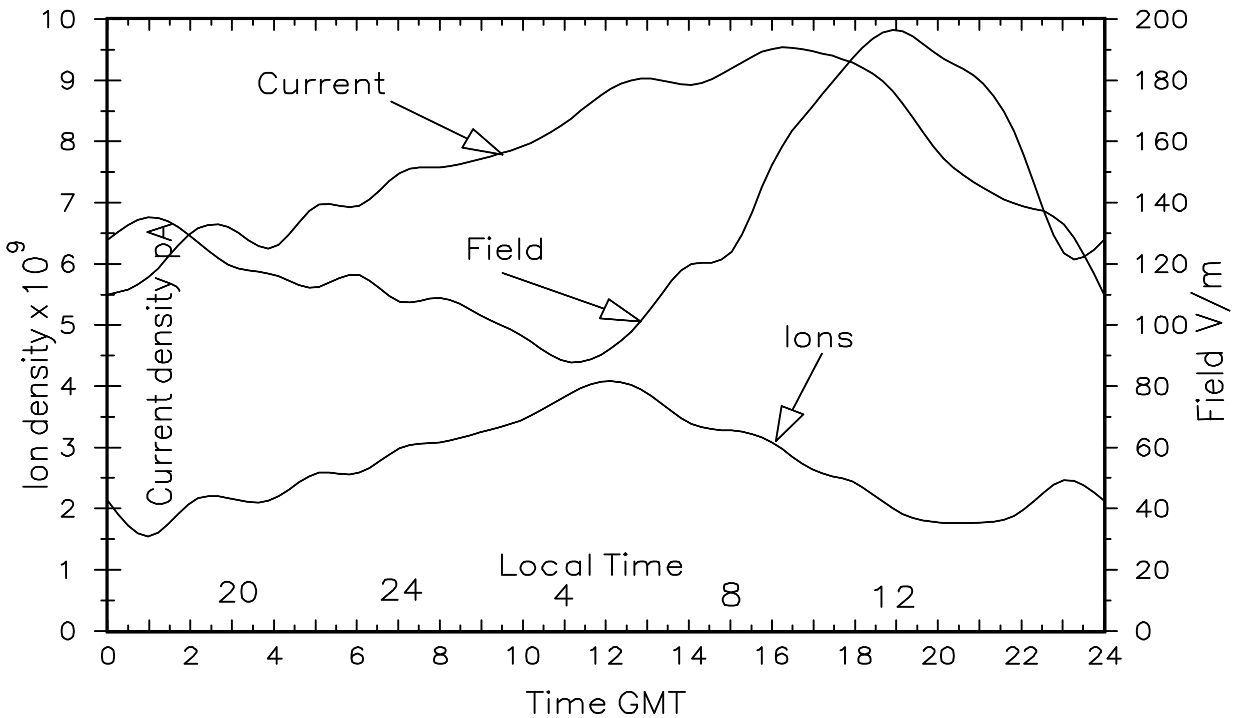

Fig. 49. Diurnal variations of electric field, ion current and ion density from 16 fairweather days in Dec. 1990.

7.2. MEASURING TECHNIQUES

Electric field is obtained by measuring the potential on a 5 m long wire suspended horizontally one meter above ground. A radioactive source (Po 220) attached to the wire assures good electric conduction to the surrounding air. Air to earth current is collected on an electrically insulated one square meter copper plate situated at the earth's surface. Gerdien ion counters record positive and negative ion densities in the atmosphere. The ion density, which is proportional to the conductivity of the atmosphere, is responsible for the air to earth leakage current. Relative humidity, temperature, wind velocity and barometric pressure are measured by conventional methods.

7.3. RELIABILITY OF MEASUREMENTS

Since the atmospheric electric parameters obey Ohm's law (Wåhlin, 1992). it is possible to test the reliability of the measurements by simply comparing the recorded ion concentrations to the calculated ion concentrations obtained from the recorded electric field and current density data or

$$(n^+ + n^-) = \frac{i}{Eq\overline{m}} = \frac{l}{q\overline{m}}, \tag{16}$$

where $(n^+ + n^-)$ is ion density of small ions, q ionic charge, E the measured electric field strength, $\overline{m} = 1.5 \times 10^{-4}\,\mathrm{m^2V^{-1}s^{-1}}$ average ion mobility in Boulder, i the measured air-earth current density and l the conductivity. If the product of $\overline{m}$ and q remains constant then the ratio i/E has to be proportional to the ion density $(n^+ + n^-)$. Since q is a physical constant it is important that the average ion mobility remains the same during the measurements or the test will fail. Because the ion mobility is solely related to the molecular collision frequency in air only changes in atmospheric pressure is of concern. However, the overall pressure changes during fairweather are normally much smaller then the accuracy of the ion concentration measurements and can therefore be neglected.

If the calculated ion densities from Equation (16) are the same as the recorded ion densities then the reliability test of the measurement would be 100 percent. Fig. 50 shows such a test for the data presented

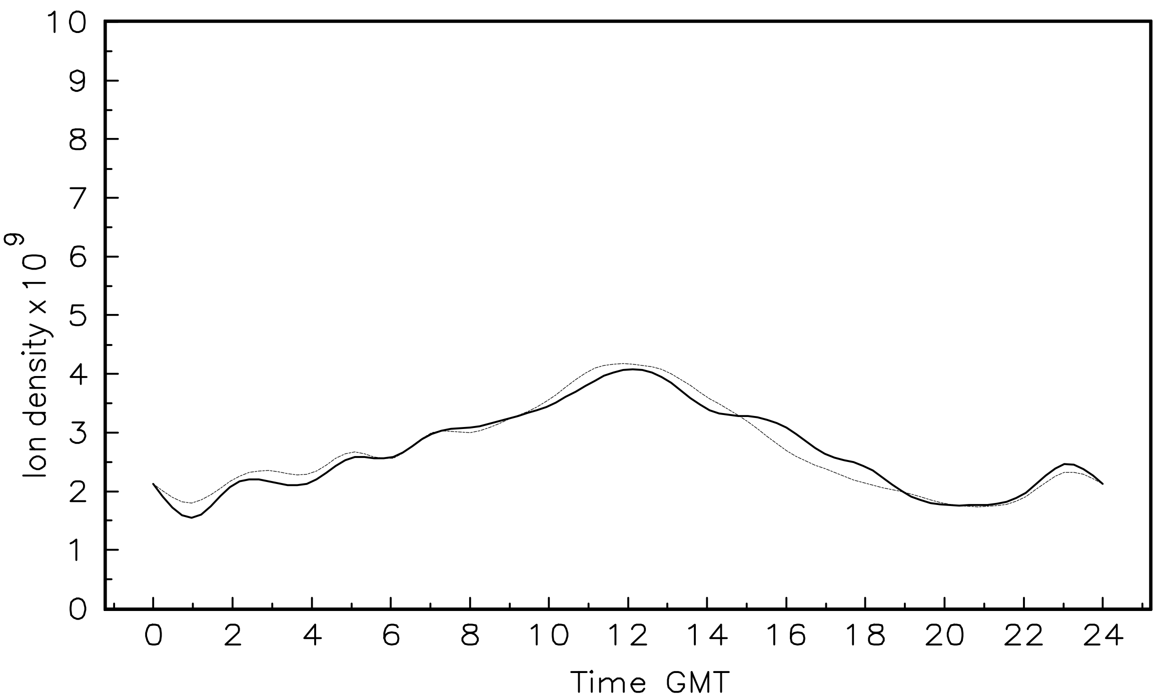

Fig. 50. Reliability test of the data in Fig. 49.

in Fig. 49 and the result reveals an average reliability of better than 95 percent over a time period of twenty-four hours.

7.4. RESULTS

At first glance there appear to be no correlation between the diurnal changes in the electric field, current density and ion density in Fig. 49. Closer examination however, shows that there are two processes at play which are superimposed on each other. One process relates to the diurnal changes in power delivered by the fairweather generator and the other to changes in electric conductivity of the atmosphere caused by the diurnal variation in ion density. For example, changes in generator energy or power, field $\times$ current density $(Ei)_g$, will cause the electric field and current to increase and decrease in unison *i.e.* the current and field follow each other. Changes in conductivity (ion density) on the other hand, will produce changes in both current and electric field but in opposite directions. For example, a rise in ion density will bring about an increase in leakage current but a drop in the electric field strength due to the increased current drain. This will cause the electric field and current to vary in strength in opposite directions and to appear 180° phase shifted relative to each other over the diurnal period. The curves in Fig. 49. also show that the power Ei (field $\times$ current density), produced by the fairweather generator reached a maximum around local noon where both the electric field and current density approaches peak values. Furthermore, an increase in leakage current and subsequent drop in electric field strength due to a higher ion concentration can be observed during the early morning hours.

The two superimposed processes described above can be separated from each other by artificially removing the changes in the resistive load caused by the variation in ion density or by removing the changes in the fairweather generator power over the diurnal cycle. Removing the variations in ion density, which is accomplished by assuming a mean diurnal ion density of $N = 2.6\times10^{9}$ ion pairs/m^2, will disclose changes in the electric field and ion current density brought about by the fairweather generator, see Fig. 51. The curves in Fig. 51. are constructed from the following equations

$$i_g = \left[\frac{N-(n^+ + n^-)}{2} + N\right]\frac{i}{N} \quad \text{and} \quad E_g = NE\left[\frac{N-(n^+ + n^-)}{2} + N\right]^{-1}. \qquad (17)$$

Note how the electric field and ion leakage current vary in phase or follow each other over the entire diurnal cycle.

Removing the changes in generator power on the other hand, brings out the variations in the electric field and ion leakage current caused only by changes in conductivity or ion density, see Fig. 52. This is

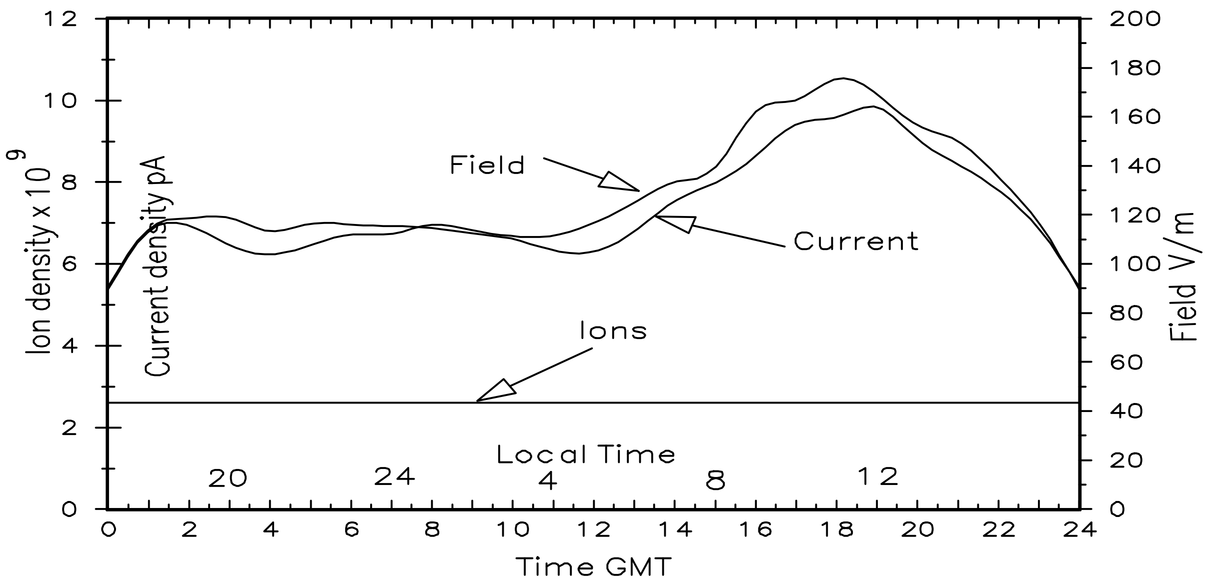

Fig. 51. Diurnal changes in the fairweather generator.

achieved by assuming a constant power output of $P = 7.6 \times 10^{-10}$ watts from the fairweather generator over the entire diurnal period. The equations used to calculate the variations in the electric field and ion leakage currents as a function of the atmospheric ion density and constant power is

$$i_\ell = \sqrt{(n^+ + n^-) m\, q P} \quad \text{and} \quad E_g = \frac{P}{i_\ell}. \tag{18}$$

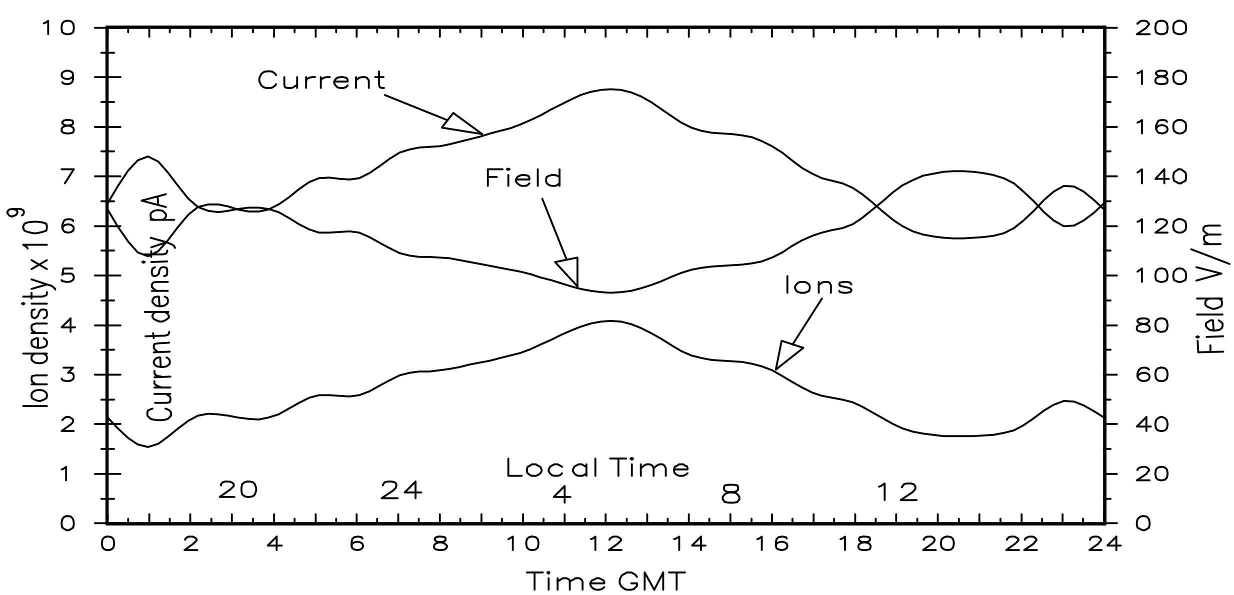

Fig. 52. Changes in the resistive load.

In contrast to Fig. 51 the electric field E_g and ion leakage current i_ℓ are now 180° out of phase or vary in opposite direction with respect to each other during the entire diurnal cycle. The fact that the ion leakage current and the electric field vary in opposite direction as a function of changes in the atmospheric conductivity is very fortunate. The reason for this is that these fluctuation will cancel each other when we multiply the measured ion current density with the electric field $(i \times E = P_g)$ to obtain the specific power of the fairweather circuit, because only the fluctuation contributed by the fair weather generator, which are in phase (see Fig. 51), will be exposed.

The fact that the product $i \times E = P_g$ only refers to the power produced by the fairweather generator is of great importance because it will provide information of the electromechanical structure of the fairweather generator itself which is not yet well understood. As mentioned in Chapter 2, Sec.2.2 and Sec. 2.7.2, the general belief is that all thunderstorms around world are the sole source of electric power delivered to the fairweather circuit and that the variation in the electric field is correlated to the number of active thunderstorms over the different world continents. This hypothesis was augmented by the electric field measurements performed onboard oceangoing ships in 1923 in the two separate campaigns known as the Maud and Carnegie expeditions mentioned earlier.

In order to test the above global thunderstorm hypotheses we selected 170 cloud-free fairweather days between the period of August 1990 to April 1992. Diurnal variations of electric field, ion current density and ion concentration for these 170 days are averaged in Fig. 53. Note the similarity to the data in Fig. 49. From the above Boulder diurnal variations we can obtain the fairweather specific generator power free from local changes in conductivity and load by multiplying the field E by the ion current density i and calculate the changes in electric field E_g caused by the fairweather generator only. (see Equation (18)). Fig. 54 shows diurnal variations in specific generator power at Boulder and its associated electric field variations in percent of average mean compared to variations in the diurnal electric fields recorded by the Maud and Carneigie expeditions.

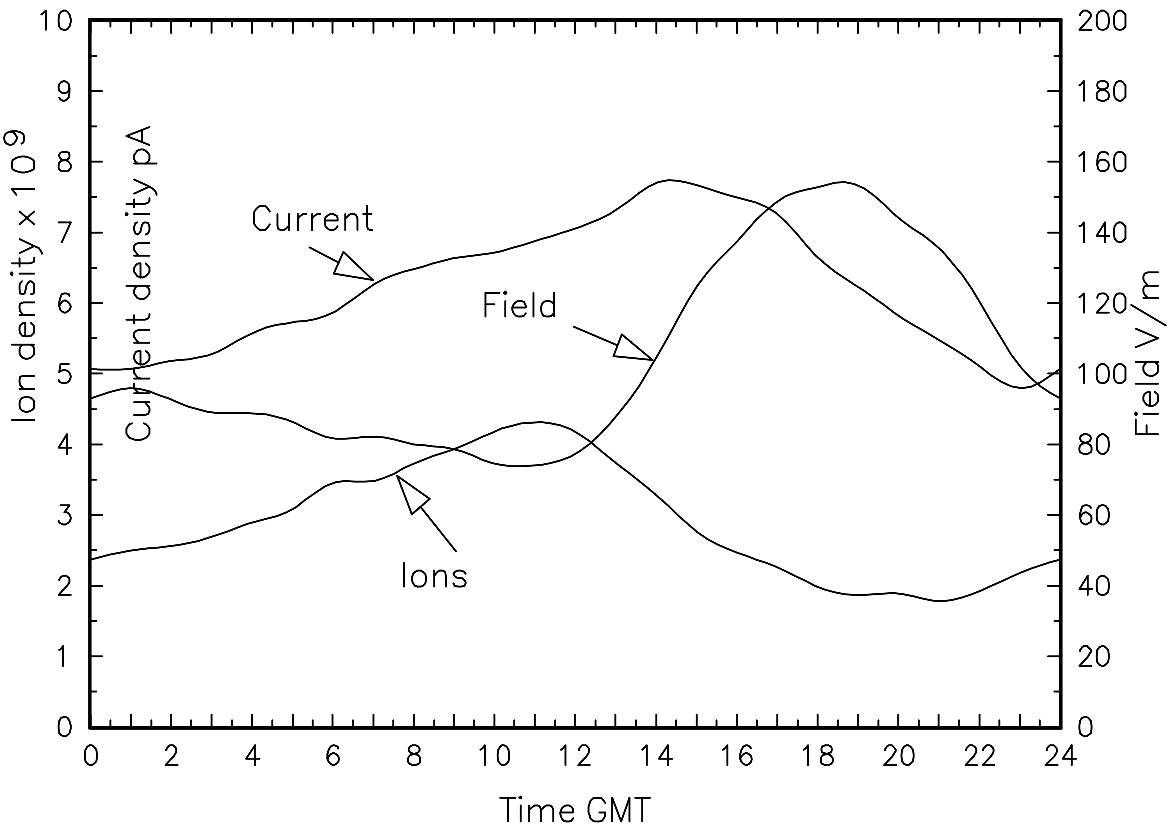

Fig. 53, The average of Electric field, ion current density and ion concentration obtained from 170 fairweather days in Boulder between August 1990 to April 1992.

The curves in Fig. 54 show a good correlation between the Carnegie and Maud electric field recordings to that of the generated E_g field in Boulder. However, since the above recordings show a maximum at about 1800 GMT which unfortunately coincides with Boulder noon hour and maximum local convection it is difficult to determine whether the fairweather field in Boulder is subject to a world wide electric circuit or a local peak in generator power due to maximum convection. A better location for testing the world wide influence, in the authors opinion, would be somewhere in Asia or Australia.

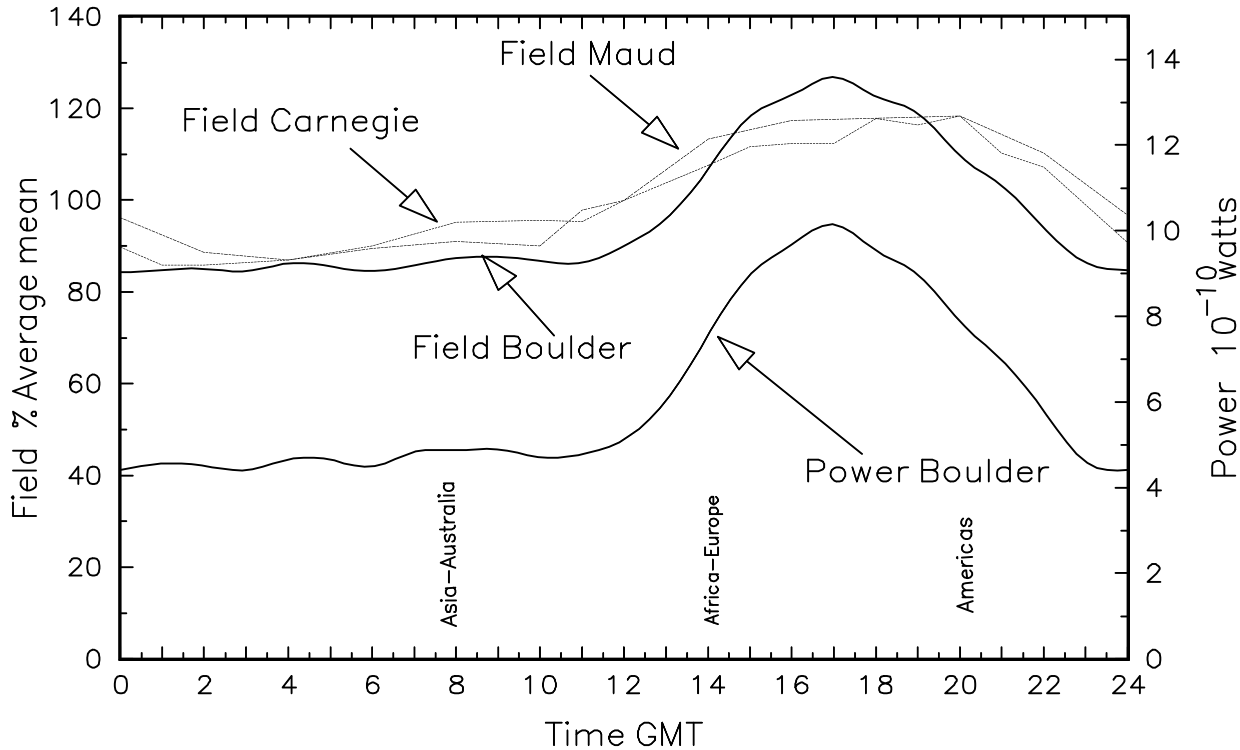

Fig. 54. Diurnal variations in electric field and power generated in Boulder compared to field variations from the Carnegie and Maud expeditions.

Another test involving two recording stations was performed in 1992. with one station in Boulder and one in Heatherwood separated by a distance of 8 km,. The idea is that if the power supplied by the fairweather generator is of a worldwide origin then the power recordings at both stations should vary in unison. However, the power variations from both stations were never the same and a typical example from two consecutive days in January 1992 are shown in Fig. 55 and Fig. 56.

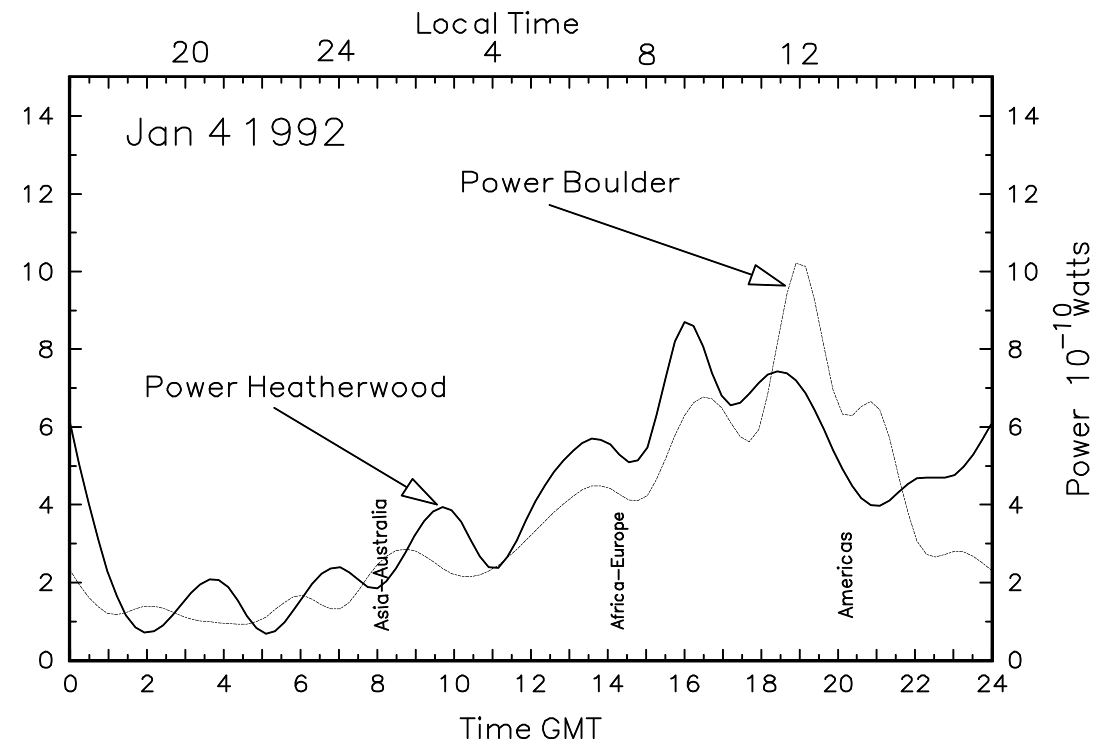

Fig. 55. Diurnal variations in specific power at two different locations on June 4 1992.

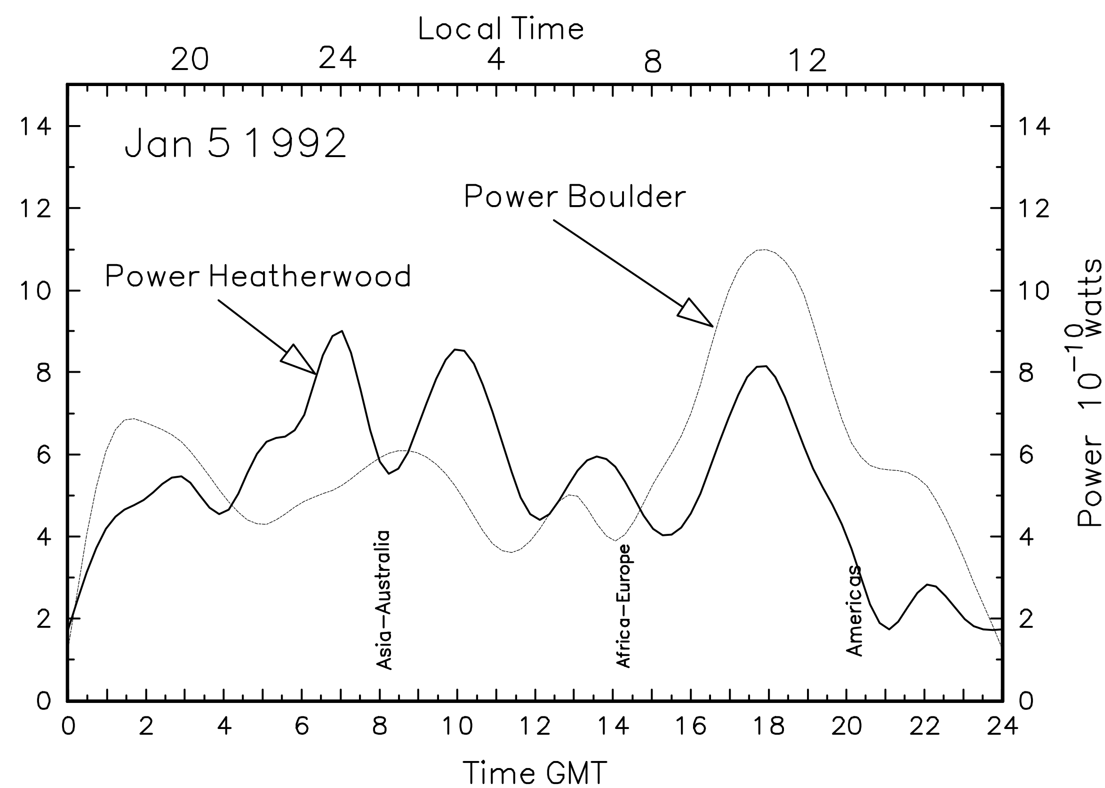

Fig. 56. Diurnal variations in specific power at two different locations on June 5, 1992.

The lack in correlation between the power curves suggests that each location is mainly subject to its own independent fairweather generator ruling out a common external fairweather generator such as the global thunderstorm circuit as the only source of fairweather electricity.

Individual variations in generated specific power, *Ei*, at different locations, leads the author to believe that the fairweather field is chiefly generated by local generators. However, since conductivity increases with altitude it is conceivable that power from other fairweather generators, perhaps as far as from other continents, could spill over from these sections of the world. This might explain a slight worldwide diurnal variation in the fairweather field and current density around the globe as reported by Simpson (1905) and Hoffmann (1923)..

One rare incident occurred on September 12, 1990 when three sudden drops and reversals in both the electric fairweather field and current density were registered, see Fig. 57. The first change appeared at 2045 GMT and the last at 2135 GMT. The last and strongest change coincided within a few second of an earth quake registered at the Golden Earth Quake Center in Golden Colorado (Minsch, (1990)). The center of the earth quake was located about 16 km east of Vail Colorado (about 100 km from our measuring station) and measured 3.0 on the R scale. One single aftershock on September 14 measuring 1.5 on the R scale was also registered simultaneously both in Golden and on our field and current density recordings in Boulder. No such rapid change or reversal in field and ion current during fairweather conditions was ever noticed before or after this occurrence during the entire two year period of continuos measurements. One possible explanation is that an excessive release of ionizing radioactive Radon gas from fissures in the earth crust, surrounding the earth quake area, might have increased the ion concentration and conductivity in the atmosphere to such an extent that a short-circuit of the local and

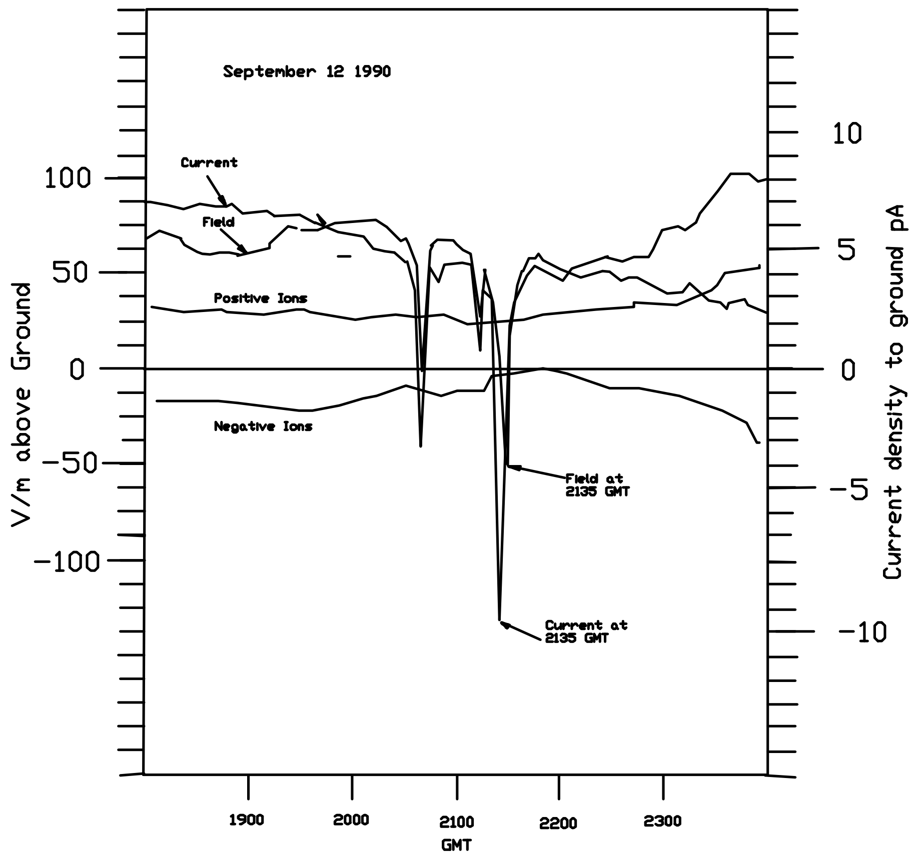

Fig. 57. Recordings during nearby earth quake.

nearby atmospheric electric environment might have occurred. However, more atmospheric electric measurement in earth quake prone areas should be made before a definite relationship between earth quakes and atmospheric electricity can be established. It should also be mentioned that a considerable drop in atmospheric electric fields has been observed by other investigators during nuclear test explosions (Harris (1955)) and after nuclear power plant accidents such as in Scotland (Pierce (1957), (1959)) and Chernobyl, USSR (Israelsson *et. al*(1986)) due to the release of ionizing radioactivity.

7.5 APPENDIX

Below are monthly means of electrical and meteorological data collected between August 1990 and May 1991.

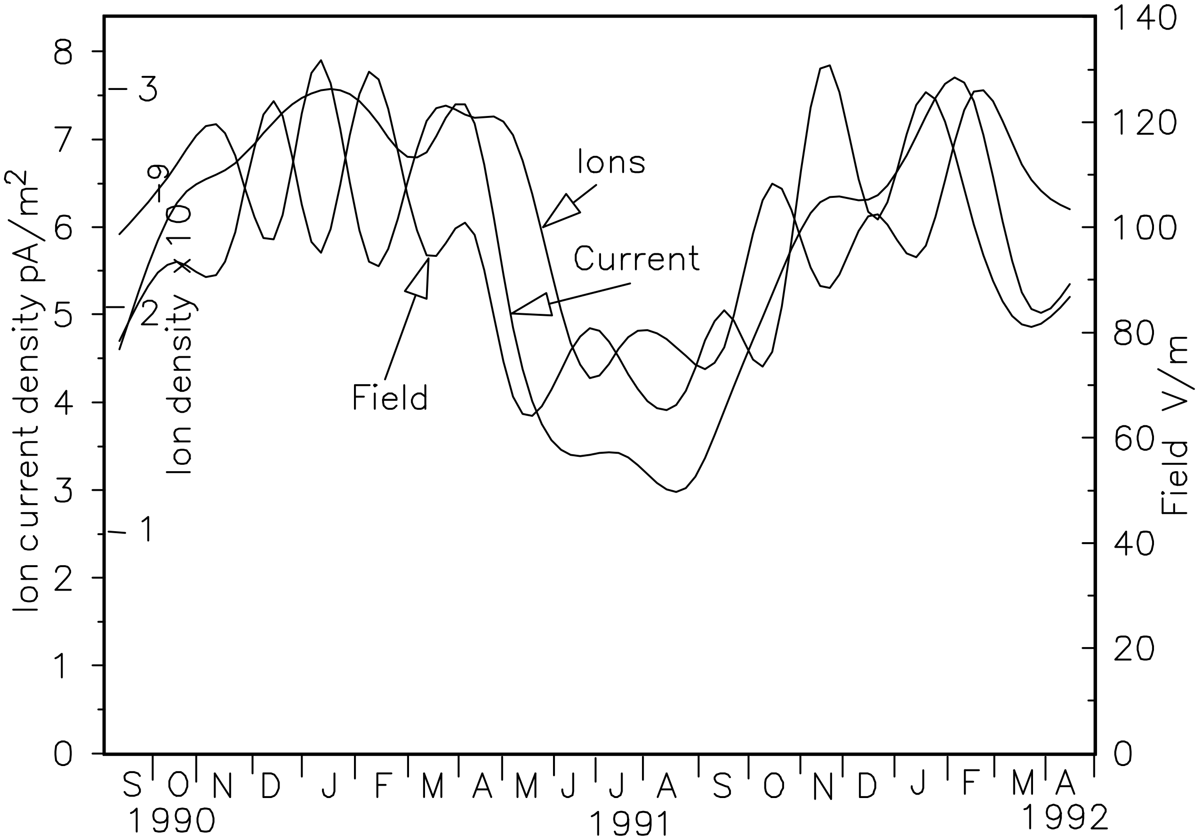

Fig. 58. Electric field, current density and ion density.

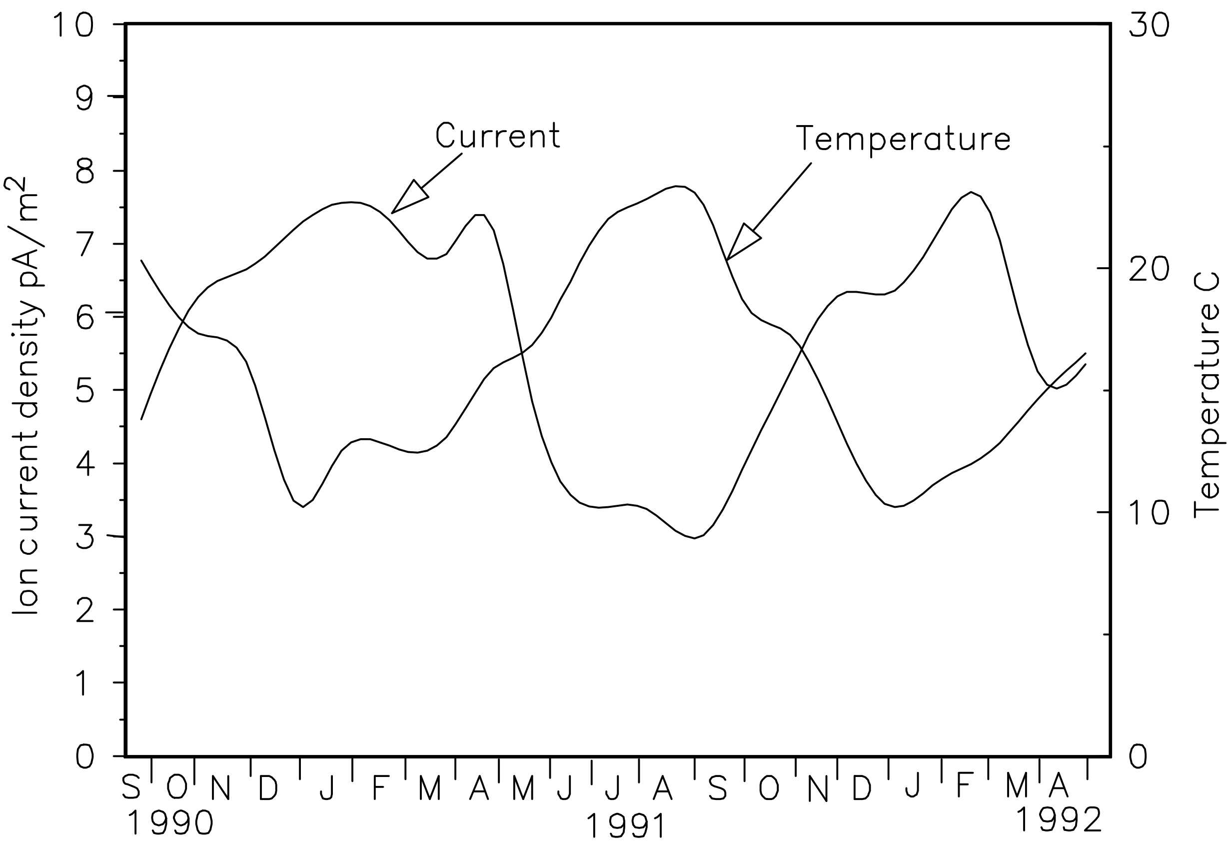

Fig. 59. Current density and temperature.

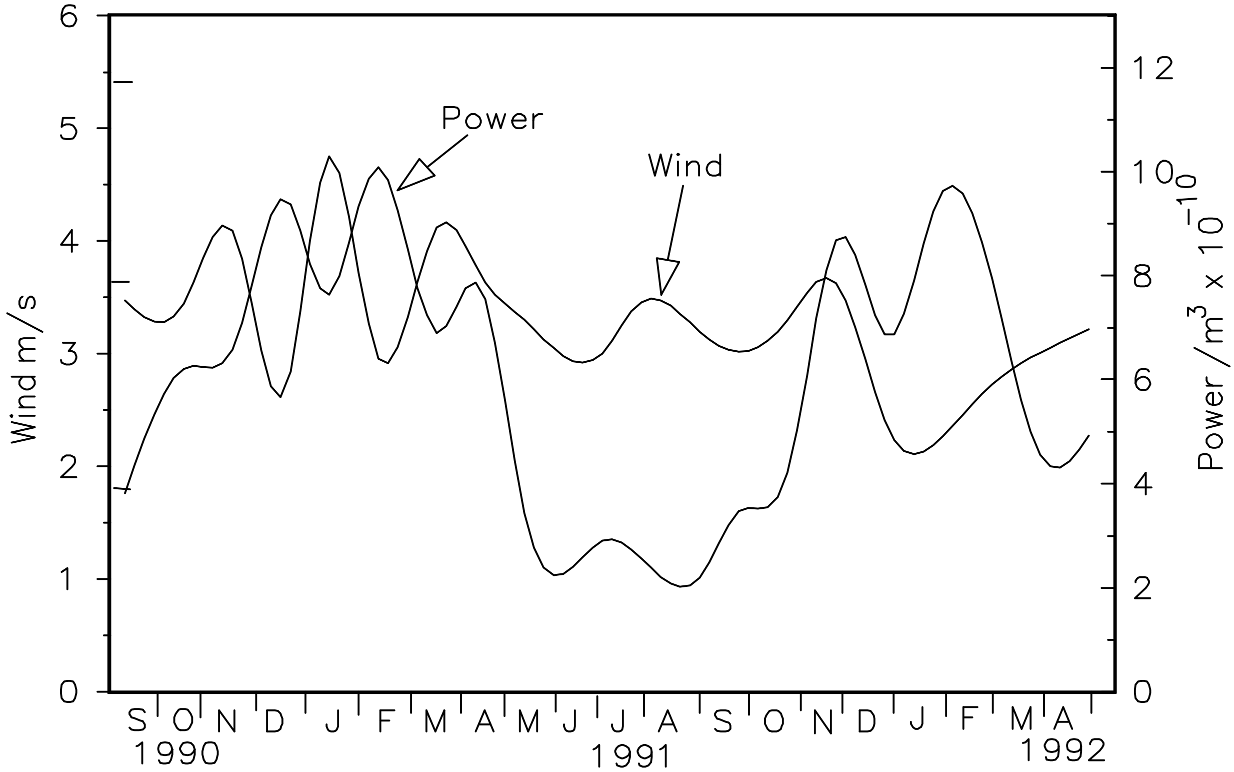

Fig. 60. Generator power and wind.

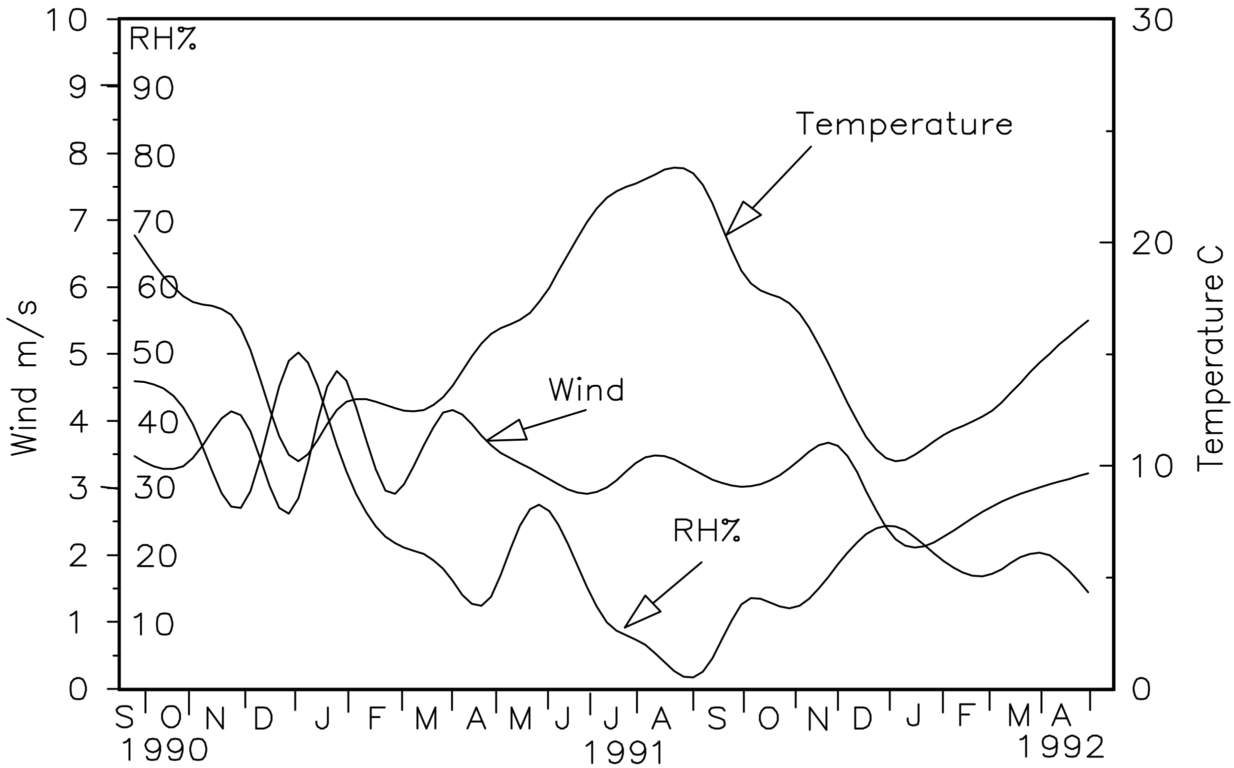

Fig. 61. Wind, temperature and relative humidity.