

CHAPTER 5

FAIRWEATHER PHENOMENA

5.1 EXPERIMENTS AND OBSERVATIONS

After Lemonnier and Beccaria discovered the fairweather electric field by probing the atmosphere with poles and stretched wires, the first considerable advance was made by de Saussure (1779) who introduced several new methods of measurements. De Saussure constructed an electrometer consisting of two elder pith balls suspended from silver wires inside a glass jar with metallic shielding. When the balls were charged to the same polarity they repelled one another and the amount of deflection was a measure of the electric intensity from a source brought in contact with the silver wires. By raising and lowering an antenna which was connected to the electrometer, de Saussure could show that the electric potential in the atmosphere increased with altitude. Another clever experiment by de Saussure was to throw a lead ball, which was connected to the electrometer by a thin wire, straight up in the air breaking the wire and electric connection. The ball, after reaching a certain potential, would take its charge with it and leave an opposite charge behind on the

electrometer. De Saussure realized that the electrostatic charge induced on his antennas was caused by a positive static charge in the atmosphere above. He is also believed to have been the first to discover the systematic annual change in the fair weather field, see section 1.5.

One interesting experiment involving the use of kites was performed by Mahlon Loomis, a Washington D.C. dentist, during the period 1862 - 1873. Loomis used two kites at the end of stranded bronze wires about 600 feet in length. The wires were both grounded through sensitive galvanometers but the ground connections could be broken by means of telegraph keys. Loomis was able to transmit morse code messages from one antenna to the other over a distance of up to 16 miles without the use of any external electric source. In the early 1870's Loomis was supposed to have achieved voice communication using a Berliner's microphone. He applied for government funds for a classified military project, but since the Civil War was over, Congress would not appropriate the money. What is important is that Loomis must have been first to achieve wireless communication but obviously not by radio but by disturbing the electric fairweather field. A member of the family, Thomas Appleby, has published a book on Loomis' experiments and copies of patents issued (Appleby 1967).

In the beginning of this century it was discovered that ions cause the atmosphere to be conductive and new theories were needed to explain how charges on the earth-atmosphere system are maintained. It has been suggested that the earth's rotation in its own magnetic field could produce a magneto effect which would drive the electric fairweather circuit, or that evaporation of water from the earth's surface might charge the earth negatively and the water vapour positively by some unknown process. In fact, Volta (1800), advanced an electrification theory based on vapourization and condensation of water in order to explain charge production in thunderclouds. Today, although the question still remains open, there are primarily two

theories dealing with the problem of the origin of the electric fairweather field. One is the closed circuit hypothesis which asserts that all thunderstorms around the world recharge the earth-ionosphere system. The other theory is the electrochemical process which is an electrostatic mechanism based on the preferential capture of negative ions by the earth's surface. The amount of charge produced by all thunderstorms around the earth at any given time is certainly adequate for replenishing the fairweather charge and the variations of the fairweather field as a function of GMT seems, to a certain extent to follow the variation in the world-wide convection pattern as shown in Fig. 15. The electrochemical charging mechanism, on the other hand, suggests that if a sphere the size of our earth is ventilated by ionized air then, by extending the curve in Figure 23, it will charge to approximately one million coulombs, a value that conforms with the measured charge on earth. The curve, of course, shows the charge on water surfaces, but it should be remembered that two-thirds of the earth is covered by water. Also, the earth's surface is constantly being ventilated by winds carrying natural ions which are supplied at a steady rate by cosmic and radioactive decay. The excess positive ions left behind near the earth's surface are carried aloft by convection and by eddy diffusion, thereby mixing through the atmosphere to heights of several kilometres. Lifting the positive ions from near ground to higher altitudes stretches the electric field lines and increases the potential. This is analogous to the contact potential experiments performed by Lord Kelvin (see section 3.2) in which the potential is increased by separating the two metal plates in his condenser apparatus. The electrochemical charging mechanism is strongly dependent on convection and is also expected to follow the world-wide convection pattern as shown in Fig. 15.

About 90% of the electric fairweather field is confined to altitudes of less than two kilometres, or that part of the atmosphere referred to by meteorologists as "the mixing region". Integrating electric field strengths up to a variety of heights will give the values of electric

potentials at varying altitudes. At an altitude of two kilometres, for example, this potential is normally about +200 kilovolts with respect to earth. At the University of West Virginia a team of physicists have managed to build an electric motor driven by the electric fairweather field utilizing an antenna extended high into the atmosphere (Jefimenco, 1971).

Since the electric fairweather field is enhanced by convection and mixing in the fine weather atmosphere, measurements of electric field strength at varying altitudes and at diverse locations may give important information about the atmospheric mixing processes in terms of local weather forecasting. Large scale forecasts might also be possible because the electric fairweather field exhibits a slight variation every twenty-four hours that is synchronous for all parts of the world. The diurnal fluctuation is linked to the fact that continental land masses of various sizes are exposed by the daily rotation of the earth to the heat of the sun and this results in convection and enhancement of the electric field (see Fig. 15).

Many other phenomena in the atmosphere can be explained by the electrochemical effect. For example, airplanes in flight, are subject to ventilation by atmospheric ions and thus charge accordingly. A Boeing 747 should reach a potential of over -100 kV by rough estimation based on Equation (7). A large body such as a zeppelin could reach a potential of several hundred thousand volts in the naturally ionized atmosphere, making a voyage in a hydrogen airship a highly dangerous venture, as proved by the mysterious disintegration of the Hindenburg in 1937.

Charging also occurs inside combustion chambers of engines where ions are formed at high temperatures. By means of the electrochemical process, ions of one sign (normally negative) are preferentially captured by engine walls, permitting those of opposite charge to escape in the exhaust stream. Exhaust charging is a common

phenomenon in our modern world. Not only do aircraft charge by this process but motor vehicles on rubber tyres become electrostatically charged even at stand still while idling. Exhaust gas from engines and smoke stacks produce excessive positive space charge over heavily populated areas. Aircraft flying through such areas during landing approaches become positively charged in contrast to what is normally experienced during regular fairweather flights. The explanation is that if an aluminium fuselage is subject to ventilation of an abnormally high positive to negative ion ratio, where $N^+ / N^- = 1.3$ or more then, according to Fig. 11, the aircraft must charge positively.

Exhaust charging also plays an important role in geophysical phenomena such as volcanic eruptions which often produce lightning and during earthquakes where a glow or earthquake light is emitted along fissures and cracks.

It is difficult to say whether atmospheric electricity has any practical applications at the present time. The structure of the fairweather field and how it is linked to convection and turbulence in the atmosphere might be of meteorological interest. The fairweather field as an energy source is too feeble for practical purposes and will only yield about 1 *mwatt* per m^2 at the earth's surface, or approximately one billion times less than solar power.

Also worthy of consideration is the fact that for the past 50 years scientists have been looking for physiological effects caused by ions and electric fields in the earth's atmosphere. Many experiments have already been performed that seem to show such a relationship. However, one still lacks concrete physical evidence and much more work is needed before one can determine the significance of atmospheric electricity with respect to one's state of health. There is also a growing interest in planetary atmospheric electricity as a consequence of data sent back from space probes.

5.2.1 EXHAUST CHARGING

Lord Kelvin was aware of the "wonderful agency in flames and fumes" causing deviations in his electrometer readings when passing through his condenser plates. Earlier (c. 1800) Volta discovered that static charges on conductors changed rapidly when exposed to candle flames or lit fuses. Modern science explains that ions produced from combustion increase the conductivity of the surrounding air causing potential gradients to change more rapidly. An increase in ion population also enhances the electrochemical charging effect. In combustion chambers of engines, where numerous ions are formed, the electrochemical charging effect often becomes a nuisance and in some cases a hazard. For example, fuel might ignite while attempting to refuel a charged vehicle or aircraft. During combustion negative ions are usually captured by the engine walls while the positive ions are carried away by the exhaust stream. The result is an accumulation of negative charge on the vehicle. Fig. 36 shows an experiment performed by the author with a diesel car blocked up on insulators. A charging current of 2 micro amperes was registered

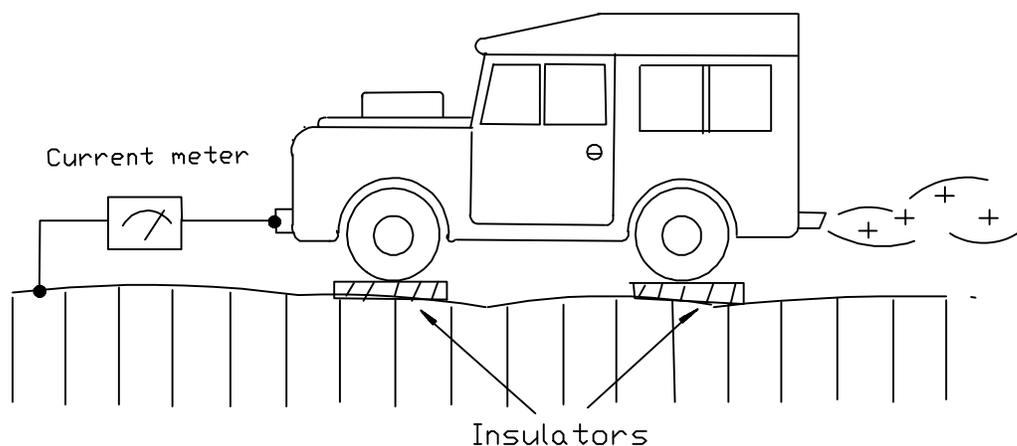


Fig. 36 Exhaust charging of a motor car.

at fast idle of the 2.25 litre engine. Similar experiments were carried out on small aircraft and negative charging currents of up to 10 micro

amperes were measured. Exhaust charging can easily produce static potentials of several thousand volts. Severe electric shocks can be obtained from large aircraft not fitted with static eliminators or by touching metal hooks lowered from hovering helicopters.

5.2.2 VOLCANIC ERUPTIONS

Volcanic plumes charge to high potentials and, just like thunderstorms are accompanied by a display of lightning discharges. Not much is known about the charging mechanism involved and very few measurements are available that can shed light on the electric structure of such plumes. Space charge measurements at ground level near volcanic eruptions reveal negative charge on precipitating ash

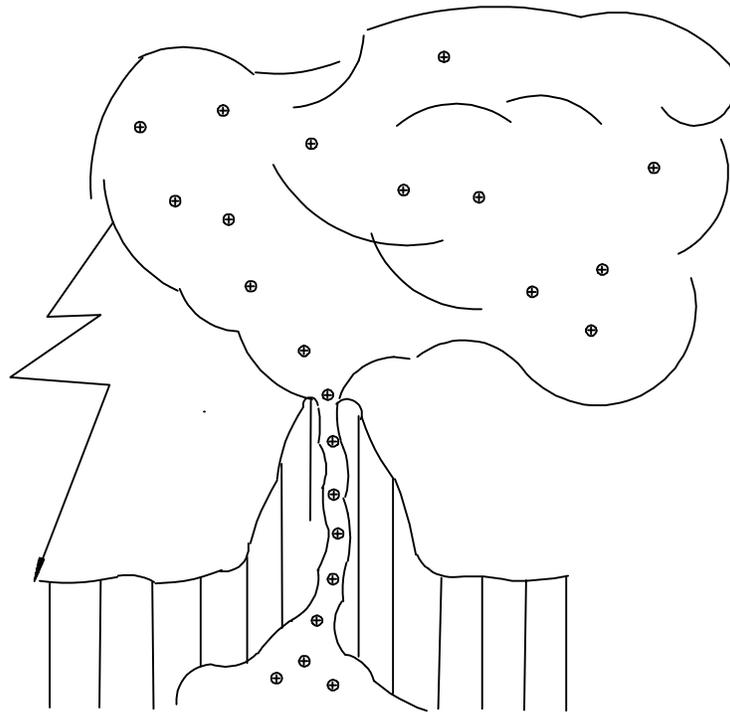


Fig. 37 Electrostatic charging of volcanic plume.

particles which, according to the mirror-image effect (sec. 2.5), means that there is positive charge on the plume above. Opposite signs have been reported and the conclusion is that ash particles from different

volcanoes charge differently. It is difficult if not, impossible to determine the dominating sign of charge in plumes from ground measurements because sign reversals, due to lightning discharges and mirror-image effects, are always present.

It has been suggested that volcanic plumes charge by frictional effects between small and large ash particles and that separation of charge is enhanced when larger particles fall out of the plume. Other charging effects to be considered are convection mechanisms and exhaust charging. Convection and condensation of water vapour as in regular thunderstorms can also explain the build-up of charge in the plume. Exhaust charging might play a dominating role since numerous ions must be present in the hot interior of the volcano. Negative ions can be expected to be adsorbed to the inside walls before reaching the earth's surface while the more inert positive ions are carried up with the plume, see Fig. 37.

Electric measurements during volcanic eruptions are obviously very difficult to perform if not dangerous. Also, volcanic eruptions are not as common as ordinary thunderstorms and data is, therefore, very sparse.

5.2.3 EARTHQUAKE LIGHT

Earthquake light is a rare phenomenon and its existence is still being questioned by some scientists. It was not before 1965, during the Matsushiro earthquakes in Japan, that actual photos were obtained of earthquake light (Yasui, 1968 and 1971). Earthquake light has been observed as a faint red and white glow for hundreds of miles around just before the earth begins to shake and crack along a fault zone. There has been much speculation on what might cause earthquake light. One fact is certain, that the light must come from atoms that have been ionized or excited by some mechanism triggered by the

earthquake. The light is emitted when a detached or excited electron falls back again into its stable orbit around the atomic nucleus. Ionizing collisions in air, between atoms and particles or between atoms and photons, by far outnumber exciting collisions. Ionization of air molecules, to the extent where the sky will glow for miles around, could be caused by corona discharges near the earth's surface or by ionized exhaust gas escaping from the hot interior below the earth's crust. It has been suggested that frictional heating of a shear zone will occur during an earthquake and that the frictional heat will lead to vaporization of water in and near the shear zone (Lockner *et al*, 1979). The result would be a drastic increase in the electric resistivity of the rock throughout the shear zone coupled with some sort of charge separation due to the evaporation of water. After enough charge has been collected in the shear zone, corona discharges along its top edge would stream into the atmosphere like St. Elmo's fire. One problem, however, is that corona discharges draw a great deal of current (100mA per cm^2) and it is difficult to understand how such a current can be supplied over a highly insulating rock surface. Also, corona is quite a noisy phenomenon unlike silent earthquake light.

Other theories take into account the piezoelectric effect in which strong electric fields are presumed to form in quartz rich crustal rocks subject to high mechanical pressures (Mizutani *et al* 1976). Again high electric fields along the fault zone would create corona and St. Elmo's fire. One interesting idea is that the sparks and crackle from piezoelectric discharges in the interior would create electromagnetic radiation, similar to that of old spark transmitters used before the invention of vacuum tubes and transistors, to the extent that the air above the earth's surface would ionize and glow. The power of the electromagnetic radiation must be high enough to ionize air and make it glow. One would expect that such a powerful electromagnetic radiation, that will cause electric breakdown of air, would cook everything else in sight and heat the earth's surface to extreme temperatures.

Perhaps the explanation of earthquake light has nothing to do with electrostatic charging but simply the escape of gases such as the radioactive element radon. According to the Handbook of Chemistry and Physics there is about 1 gramme of Radium per square mile of soil to a depth of 6 inches which releases radon into the air. During an earthquake, radon is released from considerable depths and brought to the earth's surface in large amounts. Each radon atom is capable of producing one million ion pairs. The handbook states that when radon is frozen below its melting point it will exhibit a brilliant phosphorescence which becomes yellow as the temperature is lowered and orange-red at the temperature of liquid air. The light is from ionizing collisions between alpha particles and atoms. It can be expected that when large quantities of radon escape it might be accompanied by other foreign gases trapped far beneath the earth's surface. The gases, unnoticed by humans, could easily be detected by animals and the unfamiliar scent might have a disturbing effect on their behaviour. It is believed that the Chinese are able to predict earthquakes and it is well known that they are monitoring animal behaviour for this purpose.

5.3 BIOLOGICAL EFFECTS

The exposure of human and animals to ions and strong electric fields has only very recently become an important issue in many countries. The Soviet Union, for example, has very rigorous rules and regulations concerning the exposure of workers to electric fields in power stations. In Sweden studies have been carried out on the effects of ions and strong electric fields on humans under different working environment (Lövstrand et al 1978 and Backman, 1979). Many other countries are and have been involved in similar research. The exposure to electric fields is in itself not considered important, but the production and movement of ions in electric fields are of chief concern. Ions carry

charge to the body; they are also inhaled and trapped in the respiratory system. The question is; do ions effect our physiological or psychological well being? So far, numerous tests have been performed in different environments where ion concentrations and electric fields have been changed under controlled conditions. ECG and EEG recordings, blood and urine tests as well as blood pressure and neurasthenics (headache, nausea, insomnia, tiredness) have been monitored by many investigators but no conclusive results have ever been reported. There are many who believe that negative ions affect them in a pleasant way and that an excess of positive ions have an adverse effect. The author knows of physicists who installed negative ion generators in their cars and which are turned on during long trips in the event their wives and children become rowdy. One atmospheric electrician confided that occasionally he turns on a positive ion generator, which puts his wife to sleep, so that he can watch a TV programme of his own choice! It

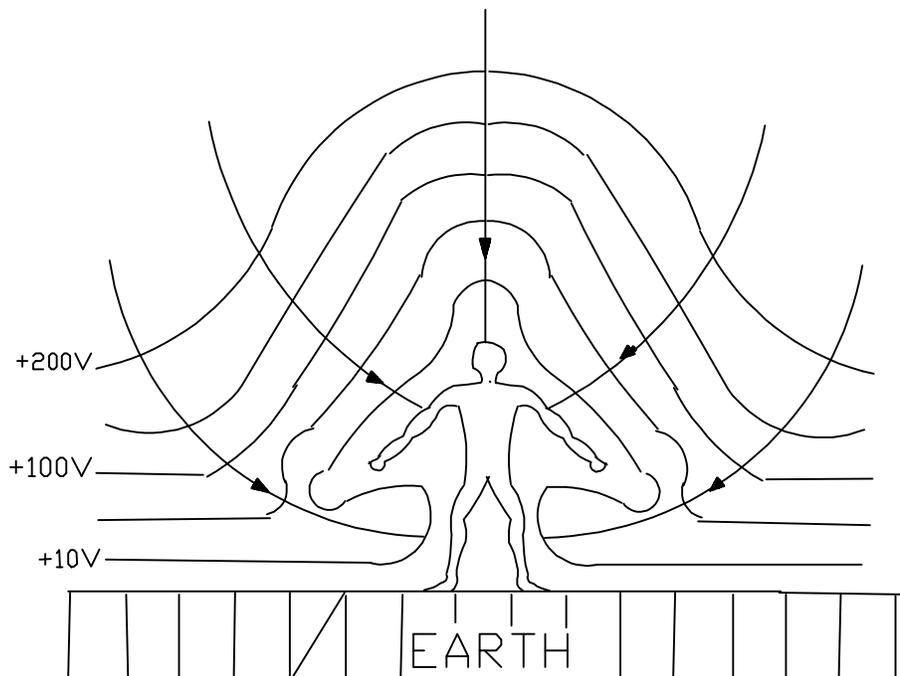


Fig. 38 A person exposed to the electric fairweather field.

has been established that ion currents produced on the human body as a consequence of the electrostatic fields, are too insignificant to

cause any noticeable effects (Backman, 1979). A person exposed to the normal fairweather field, see Fig. 38, will perhaps collect a positive ion current of 10^{-13} ampere on his head. Internal brain currents are millions of times larger and it is hard to believe that the external ion current will have any effect on the function of the brain. The effect of inhaled positive and negative ions on the respiratory system is unknown. It is possible that negative ions might have a stimulating effect on the cilia in the alveoli. The amount of ions inhaled and the sign, whether negative or positive, is strongly dependent on the electrostatic charge carried by the person in question. For example, a person walking across a carpet in an office might charge negatively to several hundred volts. The strong electric field will repel negative ions and allow only positive ions to enter the respiratory system. In fact Bach (1963) has demonstrated this effect using an insulated mannequin head biased at different electric

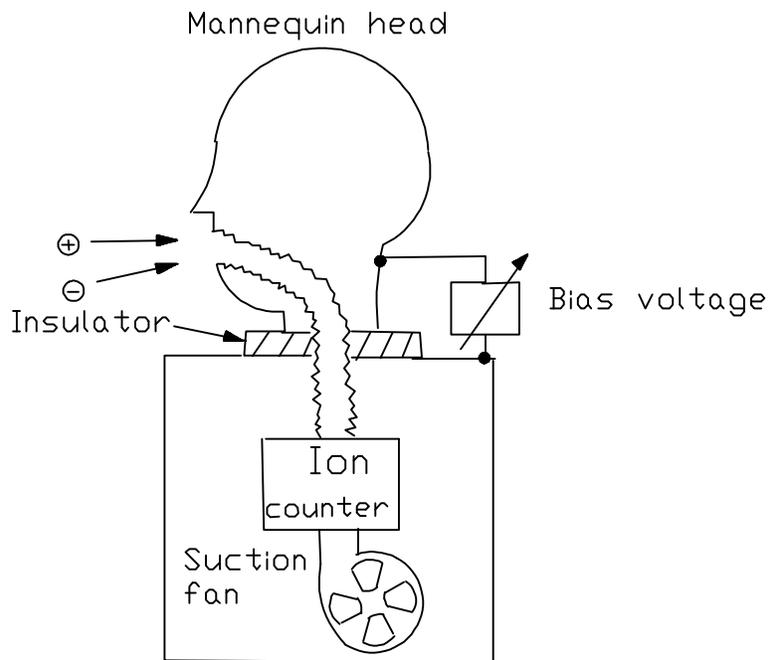


Fig. 39 Apparatus intake through the respiratory system.

potentials, see Fig. 39. The result is shown in Fig. 40 where N' represents the increase in either positive or negative ions as compared to the normal ion ratio at zero bias.

The belief that ions might have a bioelectric effect on humans and animals probably started in the Alps of Europe. It has always been noticed that during the föhn when dry winds sweep down the mountainside some people become depressed or develop head-aches and that dogs and chicken tend to hide away. It has also been observed that the positive space charge or positive ion concentration

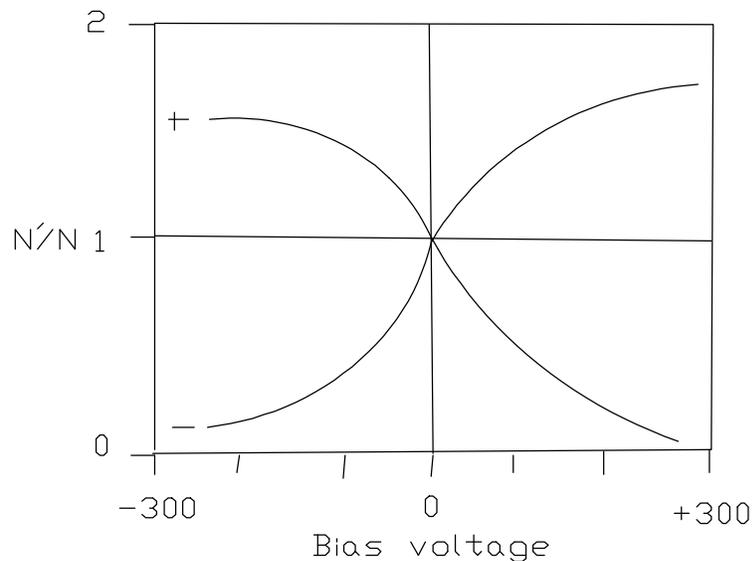


Fig. 40 Ratio of charged ions inhaled at different bias voltages.

in the atmosphere during the föhn is very high which is probably one reason why positive ions are blamed for causing discomfort amongst mountain villager. Another observation is that warm mountain winds, like the föhn, are very dry which can cause considerable discomfort as explained by Tromp (1969).

Warm mountain winds occur when cold air masses pass over mountain ranges, and when the cold heavy air reaches the other side it falls down, compresses, and heats up again. When cold air warms up it is capable of holding more water vapour and its relative humidity decreases. The warm dry air will take up water from the surrounding

environment and dry everything in sight. The Indians in the Rocky Mountain region call the dry mountain wind "the Chinook", or snow-eater, because of the rapid disappearance or vaporization of the snow in its path.

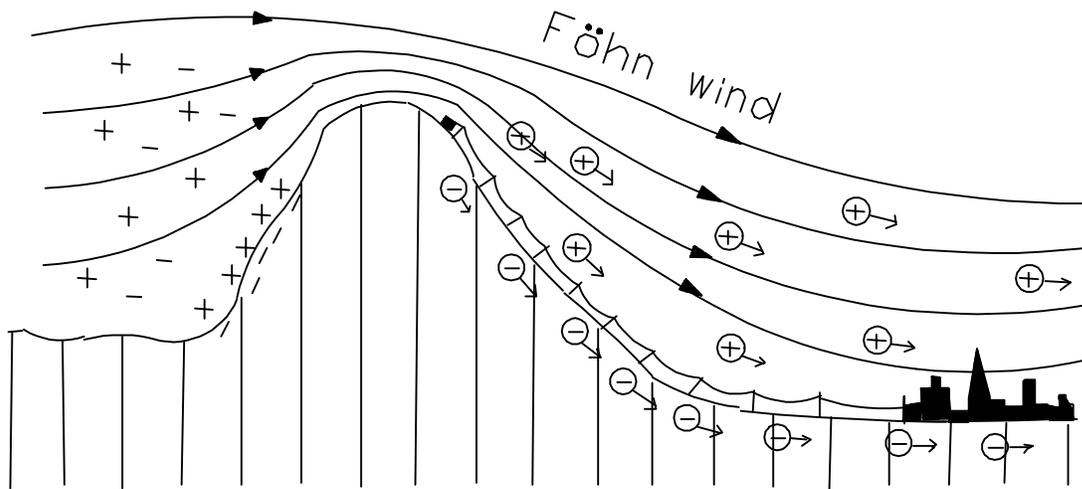


Fig. 41 Dry mountain winds (föhn or Chinook) and positive ions.

The high positive ion concentration can be explained by the fact that winds ventilating the other side of the mountain loose negative ions which are depleted by the electrochemical effect while the excess inert positive ions will follow the air stream over the top, see the diagram in Fig. 41. As the positive space charge moves down the mountain side it is followed by an induced negative image charge along the earth's surface. The induced negative charge is particularly noticeable on telegraph lines going up and down the mountain side. A protruding telegraph line will carry induced negative charge down the mountain which is registered as an electric current in the line flowing up the mountain.

5.4 THE ELECTRODE EFFECT

The electrostatic fairweather field near the earth's surface exhibits some very peculiar variations ascribed the so called electrode effect.

For example, the electric fairweather field can be slightly higher just a few metres above the earth's surface than at the earth's surface itself. This is due to a sudden increase of negative ions in a thin layer above the earth's surface. From Fig. 12, section 2.2, it was explained that the fairweather field can be thought of as electric field lines which connect the excess positive ion population in the atmosphere with trapped negative charges on the earth's surface. If, however, a cloud of negative ions was suddenly formed near the earth's surface it would mean that some of the field lines in Fig. 12 do not reach ground but will terminate on those negative ions. The number of field lines per unit surface area would, therefore, be less at

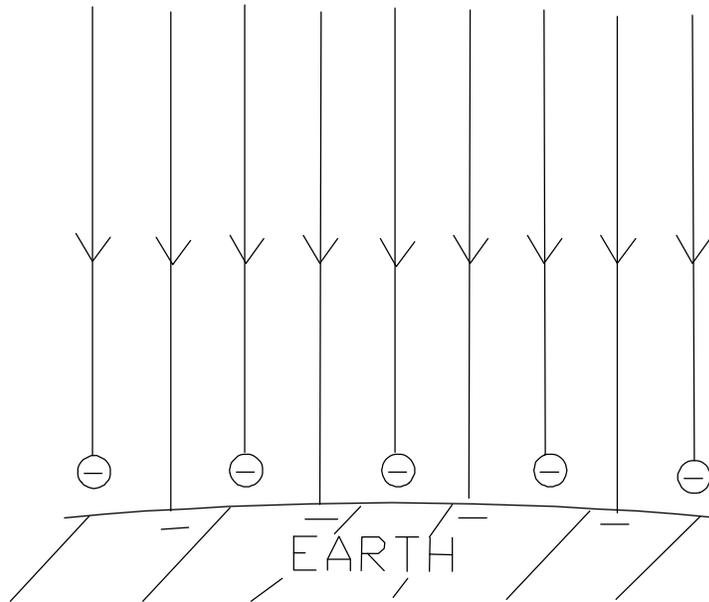


Fig. 42 The electrode effect.

the surface and higher just above the thin negative ion cloud see Fig. 42. A sudden increase in negative ion concentration near the earth's surface could be caused by the passage of a cloud above with a strong positive charge centre. The passage of a positive charge above would temporarily force positive ions to the earth's surface leaving an excess of negative ions behind in a thin layer above ground. The reverse effect is also possible when a negative charge centre passes overhead in which case there is a considerably stronger than normal electric field

very near the earth's surface. It is also believed that an electrode effect exists even in the absence of clouds. The idea is that, since positive ions congregate towards the earth's surface because of the normal fairweather field and since there is no supply of negative ions leaving the surface, an imbalance must occur with a higher than normal positive ion concentration near the earth's surface. Numerous measurements, however, do not clearly show such an effect.

5.5 INTERPLANETARY STATIC ELECTRICITY

That static electricity is present on other planets has been established by instrumentation carried on board unmanned space probes. For example, lightning discharges have been observed on Jupiter by the Voyager spacecraft (Smith et al, 1979, Cook et al, 1979 and Gurnett et al, 1979). There is also a strong belief that lightning might occur on Venus.

The rate of current carried by cosmic ray particles to the earth is about 0.2 amperes. This means that the earth will charge 280 volts per second positively unless there is a flow of electrons to the earth at the same rate. The electrons might come from the sun, in which case the sun must charge positively. The existence of strong electrostatic fields in interplanetary space is an untouched field of research. There are problems with orbiting spacecraft building up electrostatic charges which can have adverse effects on measuring instruments and data collected. Extreme charging might occur on space vehicles when returning to earth through the highly ionized layers of the ionosphere. The ventilation of ionospheric ions in combination with the electrochemical charging effect might cause the plasma discharge observed during re-entry, This makes radio communication to from the space vehicles impossible.