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Charge Potential Variation on the Earth during Harmattan Dust Haze and the Dynamics of Dust Particles

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Abstract

The occurrence of Harmattan dust haze during the dry seasons (mid-December to mid-March) and the manner of variation of electric potential gradient in atmosphere at ground level during the dust haze have been discussed. No answer is available for a satisfactory analysis of these phenomena. Once again the concept that the solar radiation carries non-electric charge is seen to play an important role in occurrence of this event. The new explanation provides a complete answer to the event.

Key words: *Harmattan dust haze, air-earth potential gradient, field reversal, earth current*

Most part of West Africa experiences the dust haze during December to March, the effect being greatest during the months of January and February. The dust haze is formed as a result of the wind blowing from Sahara and carrying fine particles of dust in it.

Measurement record during the harmattan period 1

It is interesting to note that the dust particles remain in suspension for a long period, often for several days. The dust particles in the atmosphere reduce the visibility to less than a mile. Often the height of the dust haze is in excess of 10,000 feet. During the dust haze, pronounced variations of electric field at ground level are distinctly noticed.

The period of dust haze coincides with the dry season with very low relative humidity[1]. The values of relative humidity at 7 AM and 4 PM fall below 20% and 10% respectively for temperatures of about 70^0F and 90^0F. The size of the particles ranges from 0.1 to 0.5 microns with a chemical composition, silica 50%, alumina 10%, lime 5%, ferrite 4% and magnesia 2% having small quantities of potash, soda and titanium oxide.

Harmattan effect during december 1966 to 1967 [1]

During mid-December 1966, it was recorded that the relative humidity had fallen to about 30% and 15% at 7 AM and 4 PM respectively. By this time the Harmattan dust haze made its occasional appearance. The intensity of the effects increased as the humidity continued to decrease during the months of January and February. The relative humidity fell below 10% and 5% at 7 AM and 4 PM respectively when the effect was the greatest. Fig. 5.2.1 shows these variations during the Harmattan period. During normal fair-weather condition there was a positive electric field of about 60 V/m from midnight to noon with no predictable variation during this period.

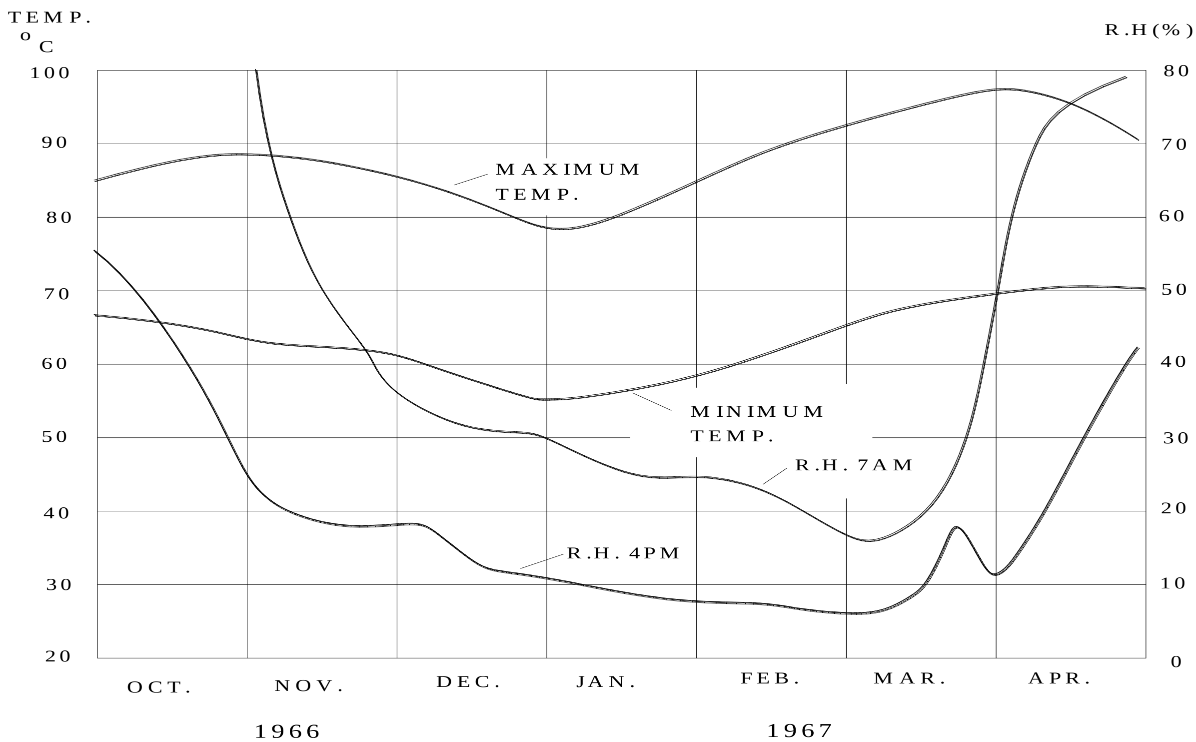

Fig. 5.2.1 VARIATIONS OF TEMPERATURE AND RELATIVE HUMIDITY DURING THE HARMATTAN PERIOD (Ref. 1, pp 42)

From noon onwards the field increased, reaching a maximum of about 100 V/m at about 20 hrs. and then decreasing to a lower value by midnight. When the effect of Harmattan made itself evident, there was a remarkable change of field in the early morning with the effect persisting throughout the day but, reverting to normal condition by evening. Fig. 5.2.2 shows the actual variation of potential gradient in three particular days, having no Harmattan effect, a mild Harmattan effect and drastic Harmattan effect. During most of the period, mid-December to mid-March, the field reversal was measured in the day time. It was consistent in making its appearance between 7 and 9 AM in the morning, being generally earlier persisting longer when the effect was greatest. There was no predictable effect of the Harmattan form the nature of field variation during the remainder of the day. The value after midnight was still reasonably constant, although the value varied during the period of measurement from about 20 V/m to 100 V/m. The rate of change of field from this value to large negative field was surprisingly rapid. The field changed from its normal value to its field reversal condition within 30 minutes, and sometimes within 10 minutes, with little prier indication that a change was imminent. There were some cases when this change was preceded by a rise of field by about 50 %, but this was not predictable. During the large negative field condition, considerable fluctuation in the field occurred. The maximum field recorded during this period of measurement was -5000 V/m. For even the severest case, the field recovered to its normal value by 19.0 hours, and then had a similar variation with time up to midnight as it happens for the field in fair weather condition, reaching a maximum value at about 20.0 hours and decreasing thereafter to midnight. The measurement of current shows that an increase in magnitude, and a change of polarity of the air-earth current accompanies the field reversal and intensification.

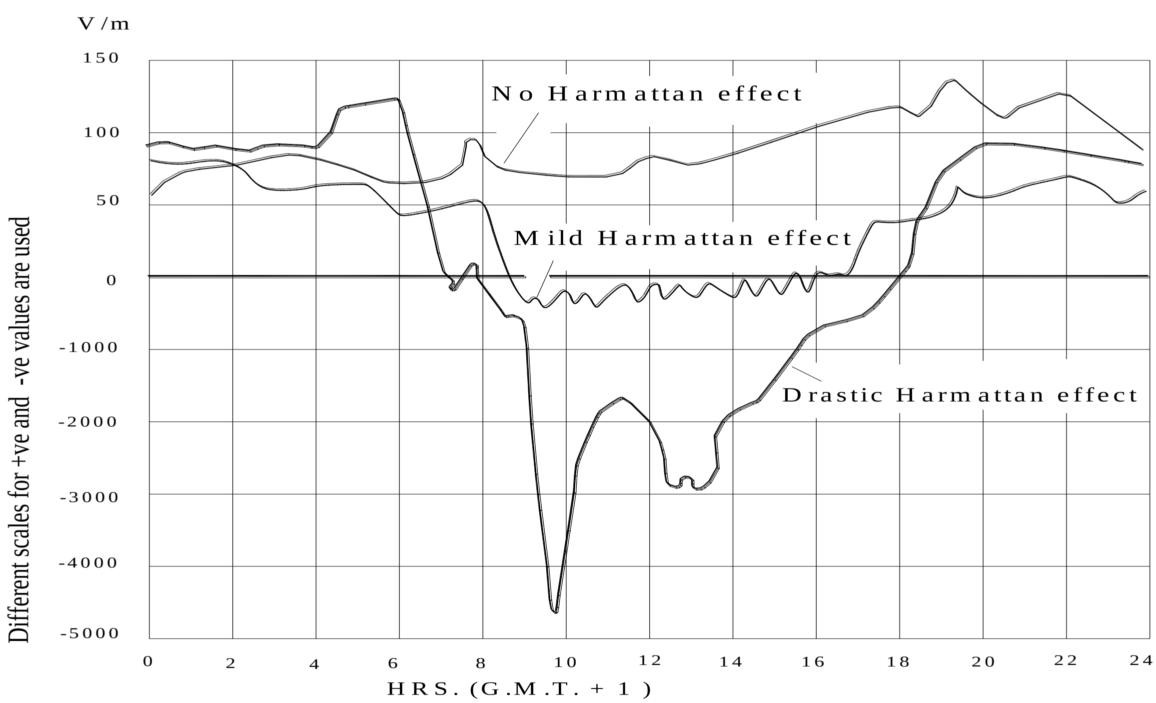

Fig. 5.2.2 NATURE OF VARIATION OF ELECTRIC FIELD DURING HARMATTAN DUST HAZE (Ref. 1 pp 43)

It is known[1] that, during the Harmattan period, there is a marked surface inversion with winds calm or gentle during the night, and that dust tend to settle from the lower layers of the atmosphere, and probably also becomes concentrated in the inversion layer. After sunrise convective turbulence begins to mix the layers of air, raising the dust from the ground and bringing it down from the inversion layer. The dust then becomes more evenly distributed through the lower atmosphere during the day.

The initiation of the effect soon after the sunrise suggests that the solar radiation is an effective agent in producing the field reversal. According to present scientific analysis, the solar radiation is effective in two ways. It can produce ions by photo-ionisation and it can cause movement of air due to heating of the surface of the Earth. This latter effect could also be ion producing due to frictional effects between the various constituents in the dust-laden atmosphere. It is obvious that ion production mechanism itself is not sufficient, since ions are produced in pairs. Some mechanism of charge separation is essential. It may be that the charging mechanism occurs at some remote place and that negative ions alone are incident on the area of measurement, but this is not likely.

Some questions are yet to be answered are[1]:

1. What is the dust charging mechanism?
2. Is it effectively a dipole layer with charge separation giving the upper layers a positive charge and the lower layers a negative charge?
3. Why does the effect start with such dramatic swiftness at a fairly predictable time in the morning?
4. What is the effective current path during the field reversal period?
5. is it from one part of the surface to another or is there a mechanism whereby the upper atmosphere can receive positive charge?

A new analysis for the charge activity during the harmattan

The surface of the Earth and its atmosphere can no more be considered charge neutral. The surface of the Earth remains at a lower potential compared to the atmosphere above in fair weather condition. The electric field in the lower atmosphere is considered positive if the potential increases with height. During the Harmattan dust haze the earth current, air-earth current and the electric field pattern undergo drastic change as discussed above. It has been discussed under the earth current topic that the surface of the Earth gains positive charge by receiving solar radiation and release negative charge while radiating to open sky. The exact mechanism of electrical charging in micro domain by radiation is different from the photoelectric effect.

In this Chapter, like the analysis of the earth current, we would analyse the Harmattan phenomena by assuming the thermal and electrical charging by radiation.The surface of the Earth becomes positively charged (both thermal and electrical) on receiving solar radiation. Thus, the electric charge potential of the surface increase in the day side part of the Earth due to solar radiation. However, it does not continuously build up to higher and a higher value since the charge easily gets conducted to the dark side of the Earth by conduction through the surface materials (land and sea). The surface potential of the Earth in the dark side always loses charge by releasing terrestrial radiation. The conductivity of the surface soil of the Earth changes with the change of moisture content in the soil, temperature and alkalinity of the soil etc.. When the moisture content of the soil drops to very low value corresponding to less than 10% relative humidity at 70^{0} F, the electrical resistance of the soil increases (behaves like insulator) and the charge conduction is hindered. Under such a condition the surface charge state of the Earth increases with continuous inflow of solar radiation. Soon after the morning the positive potential gradient is gradually reduced and the electric field becomes zero at about 8AM. Thereafter the field proceeds in a negative direction and reaching a value of about 5000V/m and sometimes even higher at about 10 AM. Normally, one would expect the negative potential gradient to go up towards noon with increasing positive charge by stronger solar radiation. But, the soil being a semiconductor, starts conducting electrical charge due to rise in temperature. At some favourable temperature, massive transition of electrons to conduction band takes place. Such a condition appears after about 10AM, and the surface potential of the Earth decreases at a faster rate due to conduction of electrons than the rate of charging due to solar radiation. After 12 noon, the ground temperature reaches a high value which is above the transition temperature. Thus, the conductivity decreases due to rapid collisition process as it happens for all semiconductors. This makes the surface potential to increase which increases the negative potential gradient in the lower atmosphere at ground level. After 2PM the solar radiation intensity decreases gradually with time and the surface potential decreases due to weaker radiation and continuous conduction of electron to other parts of the Earth (earth current). This makes the potential gradient to be 0 in air at ground level. After evening, the surface potential of the Earth decreases due to release of terrestrial thermal radiation, ultimately reaching a value close to that prevailing under fair weather condition some time at about 8PM.

During mid-December when the relative humidity falls to about 15% at 7AM occasional appearance of mild Hermattan effect are seen. In these cases the humidity being high, fluctuations in the negative potential gradient in air at ground level are seen. This effect must have been caused due to the fluctuation in the surface potential of the Earth which in turn must have been caused due to several transitions in conductivity of the soil having relatively high moisture content.

In the above consideration of the electric field variation, we have only taken the conductivity change of the soil. However, it is also required to consider the effect of the change of electrical conductivity of the air for any possible charge conduction into the atmosphere.

When the positive charge potential of the surface soil of the Earth increases, the constituent sand particles at similar electric and thermal potential experience repulsion from the surface. The finer particles having higher surface to volume ratio and hence having higher charge to mass ratio easily overcomes the gravitational attraction due to stronger charge repulsion. This makes the fine sand particles to move upwards forming the dust haze. The maximum height that any particle can attain depends on the prevailing charge state of the surface of the Earth and the charge to mass ratio of the particle. The fine dust particles do not settle down on the Earth by gravity because they are repelled by stronger repulsive thermal and electrical charge forces. The particles cannot go further up by the charge repulsion force because beyond a distance they are attracted more strongly by gravity. The floating sand particles can move to different height only when there is a change in the charge state of the particle or the charge state of the surface of the Earth or both.

Though we notice different types of charge field gradients at different altitude, in reality, the atmosphere of the Earth has a highly polarised shell, sub-shell, sub-sub-shell... structure as a global feature under fair weather condition[2]. And further, the electrically charged shell, sub-shell structure has a pattern with alternate change of polarity. The global polarised structure loses its significance at lower atmosphere during the day time part of the Hermattan dust haze when the natural charge potential of the surface of the Earth is disturbed from its normal fair-weather values. Thus, when the fairweather condition is restored at night, the charged dust particles in the atmosphere experience a different type of electric field interaction resulting from the polarised shell structure. This makes the dust particles to settle in inversion layers.

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