



ANALYSIS OF EARTH CURRENT AND THE NATURE OF VARIATION OF ELECTRIC POTENTIAL OF THE EARTH

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Abstract

The nature of earth current and its manner of systematic change has been well recorded. The earth current pattern in fair weather condition measured at several points on the surface of the Earth reveals its global phenomena having bearing with solar events, lunar cycles etc.. The most conspicuous feature of all hodographs prepared in fair-weather condition is that the electric potential gradient vector undergoes a fluctuation with twice maximum and twice minimum values. No plausible explanation is available for many of these observed events, ultimately leaving them as mystery. The author of this book made an unconventional approach by introducing a non-electric form of charge to radiation particles. This new concept, besides supplementing the dynamics of celestial bodies, is also found to provide a satisfactory theory for the complete analysis of earth current discussed in this article. This new concept of photon having a thermal charge and its conversion to electrical charge in different domain, under favourable condition provides a new scope of understanding of light without duality.

Key words: *earth current, vertical earth current, solar diurnal variation, lunar diurnal variation*

Everywhere on the surface of the Earth, a kind of strange electric current is seen to flow as a natural phenomenon. The flow of electric current is necessarily caused by a potential difference. Thus, there is a definite pattern of potential structure on the surface of the Earth formed by some energetic action which produces the earth current.

Earth current was first discovered soon after the first commercial telegraph came into operation when the communication message was found to have been interfered by some unknown current in the Earth. Subsequently it was confirmed by measurement that there is always a charge flow within the surface matter of the Earth. Occasionally this earth current comes in a surge with usually intense current values which do not appear to have any bearing on the weather and is rightly known as the earth current storms. At all other times, except the storm periods which usually lasts for short duration, the earth current has a definite slow changing pattern and the same is known as calm or quiet earth current. Though, in general the term earth current refers to a flow of electric charge anywhere on the surface of the



Earth. The flow of charge on the profiles of mountains being nearly vertical has appropriately a specific terminology of vertical Earth current. Electric current flows in the Earth from all sides of a mountain towards the top. Proper analysis of the earth current gives a clear picture of the charge potential of the surface of the Earth.

We have seen in Chapter-3 that charge potential difference on the surface of the Earth, caused by solar radiation gives rise to different charge forces among the celestial bodies which in turn controls the dynamics of celestial bodies. Thus, it may be useful to consider the same mechanism for the electrical charging of the Earth by solar radiation and verify the concept if it agrees to justify the Earth current phenomenon.

Nature of the earth current ¹

The earth current phenomenon has bearings with the changes in geomagnetism, disturbances in ionosphere, occurrences of solar flares, polar lights and periodic variations of the sunspot number etc.. The nature of the earth current and the manner of variation responding to the above parameters are dealt in reference 1 under terrestrial electricity. Some important features only are discussed below.

Earth current storms ¹

While some of the disturbances in the earth current occur more prominently in polar region, the others happen everywhere in the Earth and at the same time. Studies on earth current and geomagnetism reveals that there is a similar correspondence between the two events. Both the events are associated with the occurrence of auroras and high sunspot number. The storms often repeat after 27 days which is the period of rotation of the Sun.

Solar diurnal variations ¹

In quiet or calm days, the earth current change in a fairly regular manner during 24 hours of the day. Fig. 5.1.1 shows a record of the Northerly and Easterly potential gradients of the earth current in successive quiet days at Tucson, Ariz... It is interesting to note here that both components of potential gradient of earth current have two principal maxima and two principal minima.

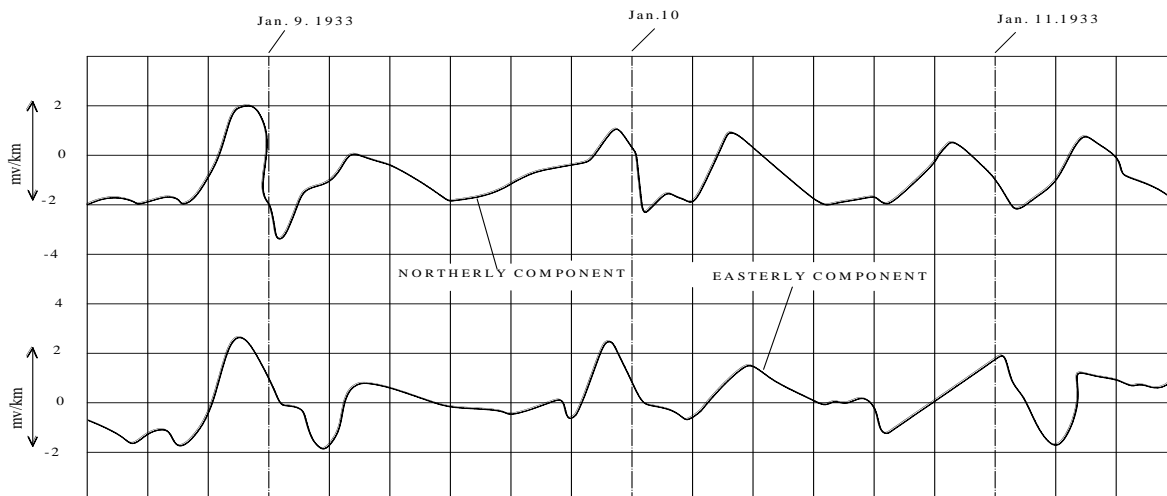


Fig. 5.1.1 MEAN HOURLY VALUES OF NORTHERLY AND EASTERLY EARTH-CURRENT POTENTIAL-GRADIENTS ON THREE SUCCESSIVE QUIET DAYS AT TUCSON, ARIZ. (Not to scale)
(Ref. figure 2 ,pp526, Terrestrial Electricity)

Seasonal changes also occur in diurnal variation. The changes in Earth current are described in the hodograph of the potential gradient vector (Fig. 5.1.2). It may be seen from the hodograph that during the hours of daylight, the gradient is much larger and changes direction rapidly as compared to that of night. The hodographs differ considerably from one place to another. However, all of them have nearly elongated shape like the one shown in Fig. 5.1.2. Even though the hodograph in some cases is close to the major axis, the current changes to opposite direction usually twice every day. Almost all observations made along the Atlantic coast of the United States show that when the electric current flows from sea to the land area, their direction is nearly perpendicular to the coast line. The amplitude of earth current increases with the increase of sunspot number but the shape of the hodograph remains unchanged. The hodographs are seen to be larger during spring to autumn as compared to winter and in some months, changes its shape.

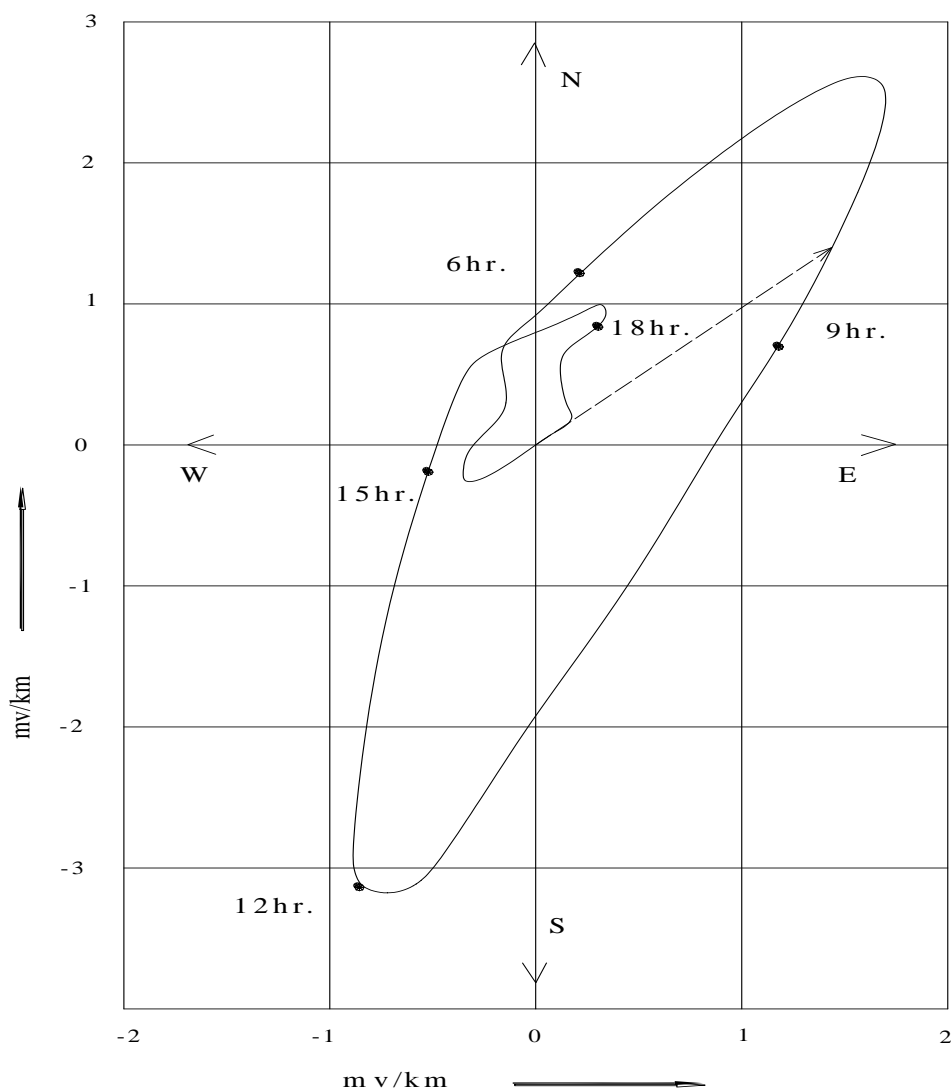


Fig. 5.1.2 HODOGRAPH REPRESENTING THE POTENTIAL GRADIENT VECTOR OF THE AVERAGE DIURNAL VARIATION OF EARTH CURRENTS AT TUCSON, ARIZ. FOR 10 QUIET DAYS EACH MONTH FOR 1932 TO 1942, INCLUSIVE

Lunar diurnal variation ¹

Because of the difference in the length of lunar day and the solar day, it is possible to separate the lunar component of the earth current variation. By doing so it is found that there is a lunar diurnal variation of double period but having the amplitude of only one fifth the solar diurnal variations. A similar diurnal variation of geomagnetism is also seen corresponding to the lunar day.



State of understanding of the earth current ¹

Most facts of earth current is an observationally recorded fact without explanation. We are yet to establish a theory that explains the exact nature of earth current in a complete manner. As regards the earth current phenomena in quiet-days, many questions remain to be answered. Some such questions are:

1. **Why the world-wide system of electric eddies is fixed with respect to the Sun?**
2. **Why the amplitude of earth current is more during the day?**
3. **Why the shape of the hodograph changes with season?**
4. **Why should it vary with size and number of sunspot?**
5. **Why should it change with lunar day?**
6. **Why should there be a vertical earth current for all mountains?**

Towards a possible mechanism for earth current

The fact that we understand very little about the cause of earth current, breeds doubt in our mind about the basic theories on charge separation in micro and macro domains. Due to the limitation faced in conventional analysis of earth current, this author has made an unconventional approach for a better answer.

It is well known that in fair-weather condition, the surface of the Earth always remains at a negative potential with respect to the atmosphere above. At the same time, it is also recorded that there is a continuous flow of positive charge from air to the Earth (i.e. the negative charge from the Earth to air) in fair weather condition. This kind of charge flow clearly indicates that there is a definite global process of electrical charging and discharging of the surface of the Earth. Variations in the degree of above charging and discharging processes from one location to another develop a potential difference that causes the earth current. As on today, the exact process by which the surface of the Earth is negatively charged is not known. Analysis of the global earth current pattern reveals that the intensity of the incoming radiation (predominantly solar radiation) and the outgoing terrestrial radiation is of vital importance in understanding the mechanism of electrical charging of the surface of the Earth.

It looks mysterious, why the negative charge of the surface of the Earth does not get neutralised with constant inflow of positive charges from the atmosphere. Perhaps, the mechanism of the return flow of charge from Earth to air takes place, in disguise, through particles carrying some non-electric



form of charge. And further these new forms of charges have the scope of converting to electrical charge in matter under favourable condition. The solar radiation entering the surface and the terrestrial radiation leaving the surface has a good scope of changing the charge state of the surface of the Earth. For visualisation of this new concept, the author would like to discuss the water cycle of the planet which has a similarity with the charge cycle.

The surface of the Earth contains some definite quantity of water. During rain, drops of water always fall from air to the Earth. The rainy season, however, is always present in some parts of the world. Thus, one may find that there is always an inflow of liquid water from air to Earth. Suppose, we understand water only in its liquid state and do not know that water vapour is another form of water in a different state. With this background knowledge, it is quite natural for anyone to wonder why the water level on the surface of the Earth is not rising with continuous addition of rain water. This kind of thinking has a similarity to the thought why the negative charge state of the surface of the Earth is not neutralised with continuous flow of positive charge from air to the Earth. We, however, know that water vapour is a different form of water and therefore we do not consider the flow of water alone while analysing the water cycle. We consider both water and the water vapour flow (two phase flow) to take part in the water cycle of the Earth. Hence, the amount of water entering the Earth in the form of rain water is nearly the same as the amount of water leaving the Earth in the form of water vapour. This makes clear as to why the level of water on the surface of the Earth is nearly constant.

Both water and water vapour have mass. The density of liquid water is less than the density of a single molecule of water due to the intermolecular gap in water. The rain drop is an integral body of water molecules. But in water vapour, the water molecules are free without any mutual bonding. Thus, in vapour phase, the molecules are free to move independently whereas in water drop the molecules move in an integral manner resulting the motion of the drop. The acceleration due to gravity is therefore expected to act equally in both systems (the free molecule in water vapour and the water drop). But we notice that water drops always fall down whereas the molecules in water vapour normally go up. We, however, have a different consideration for the action of gravity in gas or vapour to understand the phenomena. In a crude analysis, one might fail to perceive the presence of mass in molecules of water vapour from the very nature of its free movement ignoring gravity. He might then wonder how the mass of the Earth remains constant in spite of continuous addition of mass through the rain drops. Today we understand the water cycle mechanism well and it is no more a wonder to us.

From the above analysis, one might hope to understand the stable negative charge state of the Earth by understanding the charge cycle of the Earth while drawing analogy to water cycle.



From common sense analogy, one might assume that radiation particles in very very fine domain may carry tinny positive electric charge (in different form) from the surface of the Earth to the atmosphere to make a balance of the charge cycle. Further, these tinny charges would not sense the electric field of the Earth due to their very short-range nature of interaction. The author has already discussed these new kind charges earlier as the thermal charge. This is something like the molecules of vapour having mass been moving against gravity. Such tinny charges present in the outgoing terrestrial radiation transform to electrical charge in atoms and molecules present in the atmosphere by typical charge condensation which then, respond to electric field of the Earth causing air earth current similar to the concept of water cycle. Thus, to avoid confusion, the non-electric charges present in photon may be called light charge or thermal charge depending on their wave length. The detail of the new charge and their interaction is discussed by the author in Vol. III of this series of publication.

From the very nature of the earth current pattern it may be seen that the Sun is primarily responsible for causing a systematic electric current system in the Earth. Besides the gravitational attraction, the interaction through solar radiation and the effect of solar wind, the Sun being an electrically positively charged body,² has the ability to cause charge polarisation on the negatively charged surface of the Earth. The free electrons and ions on the surface of the Earth are not completely free for mobility due to their attachment with different molecules. The bond strength of the attachment varies from case to case. Some charge particles are relatively freer while the others may be having a relatively stronger attachment. While the Earth rotates with respect to the Sun, the free electrons in the crust of the Earth remain oriented towards the Sun due to the charge attraction from the Sun. This results a polarised charge structure on the surface of the Earth orienting in the direction of the Sun³. Thus, the free negative charges make a systematic relative motion with respect to the surface of the earth. The current pattern due to the above polarisation effect is not exactly symmetrical about the line joining the Sun and the Earth because of wide variation of electrical conductivity of different surface matter of the Earth. The concentration of electron by polarisation has a limit because, the local repulsive forces from similar charges (electrons) tries to push them apart. The above charge polarisation effect due to the Sun and the fixed orientation of the charge structure of the Earth in the direction of the Sun, provides a part answer to the nature of worldwide system of the Earth current fixed with respect to the Sun. The charge density structure in ionospheric shells and the auroras exhibiting identical orientation phenomena with respect to the Sun has been analysed earlier in the similar manner in Volume I.



Besides the polarisation effect discussed above, the solar radiation plays an important role in developing a positively charged surface. Solar radiation falling on the relatively negatively charged surface of the Earth neutralises the negative electric charge partly and therefore the day side surface becomes electrically positively charged with respect to the surface in the night side. Similarly, when the Earth cools down at night by radiating to open sky it loses the positive charge. This assumption is in contrary to the present concept that photons do not carry charge. Perhaps this apparent contradiction is a blessing in disguise as it gives rise to a new non-electric charge concept for photons. Our experimental evidence is that photon does not carry electric charge as it is not deflected in the electromagnetic field. Such experiments have a little say whether photons have any other forms of charge which do not interact with electric charge. We may redefine photon as a particle carrying thermal charge instead of associating a wave. The new definition of photon for light as a particle carrying thermal charge is a feasible reality and is superior to ordinary particle of light without charge for explaining the phenomena of light. The additional thermal charge property makes the new particle theory of light richer to compete with the wave theory of light where the role of wave length is played by the temperature potential of the thermal charge. The author is of the opinion that with this new concept of light (electromagnetic radiation), a new theory would be able to remove the prevailing duality of light. Thus, it may be interesting to realise how the non-electric charge in photon helps to understand the dynamics of celestial bodies, different charge phenomena in the atmosphere of the Earth, the phenomena of earth current and finally different phenomena of light.

The understanding of this new concept is deeply connected with the understanding of the significance of electric charge and other charges. According to this concept, all charges appear through different manifestation of matter and space. It is still interesting to learn how the signature of electric charge (tiny electric charge) in non-electric form, present in radiation particles give rise to formation of electric charge through charge condensation (modification of matter space manifestation). The author is constrained to restrict the continuation of this discussion on micro physics as the present volume has a different objective. Thus, for the analysis of topics of this volume, it may be conjectured that thermal radiation from a high temperature body when get absorbed in a low temperature body, increases the thermal charge state of the low temperature body and further it can increase the electric charge state of the body and conversely a body loses both thermal and electrical charge by radiating out. It is feasible to have conversion of one class of charge to another as basically all charges in the new concept are different manifestations of matter and space in different domains. The electric currents in the surface of the Earth when analysed by this new concept provide a complete answer to the earth current phenomena and therefore establishes faith on this new hypothesis.



Analysis of earth current - a new concept

The orientation of celestial bodies surrounding the Earth changes in a cyclic manner due to the periodic motions of the celestial bodies. The change of orientation of the Sun and the Moon with respect to the Earth produces a change in the extent of radiation received at different location on the surface of the Earth. Hence, the surface charge state of the Earth undergoes a cyclic change. The local surface charge state of the Earth increases from its terrestrial average value by receiving solar radiation. Since the Earth has a spherical shape, at any given instant only one hemisphere receives solar radiation. The intensity of solar radiation varies from one location to another depending on the effective solid angle subtended at the Sun by unit area on the surface of Earth. The charge state of the surface of the Earth at its far end from the Sun (corresponding to night), loses the positive charge, acquired during day time through the terrestrial radiation to open sky and becomes negatively charged with respect to the surface at the day time. Thus the rotation and revolution of the Earth causes a fluctuation of the surface charge state (thermal and electric charge potential) of the earth. The potential gradient formed by the above systematic potential fluctuation causes a definite pattern of Earth current. The direction and magnitude are further modified while current follows through the path of least resistance.

A hypothetical charge potential structure of the surface of the Earth having uniformly same electrical conductivity is shown in Fig. 5.1.3. But in reality, the electrical conductivity is not same everywhere. About three fourth of the surface of the Earth is covered by sea water which is a better conductor of electricity. The land mass is a semiconducting material with relatively low conductivity and varies with moisture content. Broadly, the surface materials of the Earth can be classified into two types viz. semiconducting (land) and conducting (sea). The specific nature of distribution of land and sea on the surface of the Earth modulates the earth current pattern to a great extent.

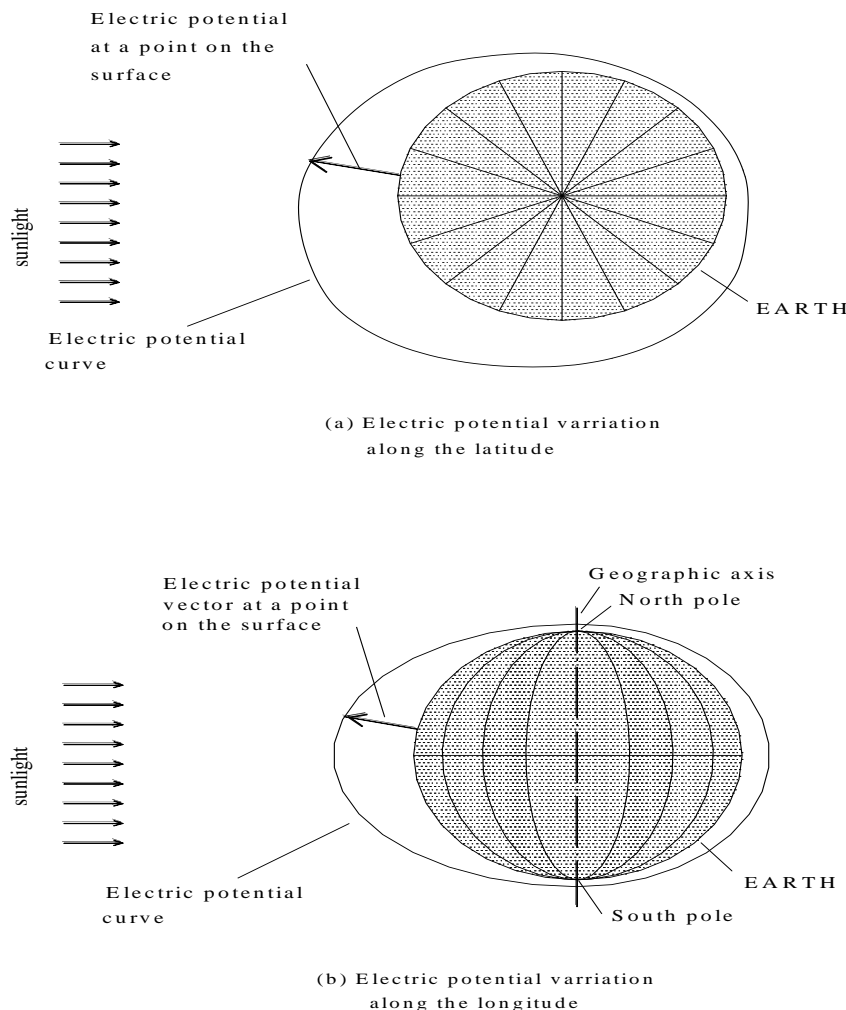


Fig. 5.1.3 POTENTIAL VARIATION ON THE SURFACE OF THE EARTH ASSUMING UNIFORM ELECTRICAL CONDUCTIVITY

The sun facing hemisphere of the Earth receives solar radiation, thus it remains at a higher charge potential than the dark hemisphere. The land surfaces on the Earth are discontinuous (continental land masses) whereas the seas of the Earth though named differently have a single continuous body. Further, the sea water being a better conductor of electricity it conducts electric charge easily from the Sun facing sea to the entire water body of the Earth. This makes the charge potential of the continental land masses to remain always higher than that of the sea in the Sun facing side of the Earth.. On the other hand, in the dark side of the Earth, the sea remains at a higher electric potential than the continental land. This nature of potential structure develops a general current system where during the day, the electric current is directed from land to sea and during the night the current is directed from the sea to the land. In both day as well as night the direction of current has to be normal to the land-sea interface (i.e. the coast line). The potential gradient from land to sea during the day is obviously

higher than the potential gradient between sea and the land at night. This fact is typically well revealed in the Earth current hodograph as the most general phenomenon. From the hodograph, it is clearly seen that the Earth current magnitude undergoes a periodic fluctuation with having twice maximum and twice minimum during the 24 hrs. day. The effect of solar radiation causing a positive electric potential on the surface of the Earth has been discussed. Further, it has been made clear how the sea and land on the surface of the Earth plays an important role in controlling the direction and the magnitude of earth current. Thus, it is natural to think that the above fluctuation of the magnitude of earth current exhibiting twice maximum and twice minimum, has its answer from the nature of variation of the ratio of the land area and the sea area exposed to sunlight during different hours of the day. A schematic picture showing the variation of land-sea area ratio during complete rotation of the Earth is presented in Fig. 5.1.4.

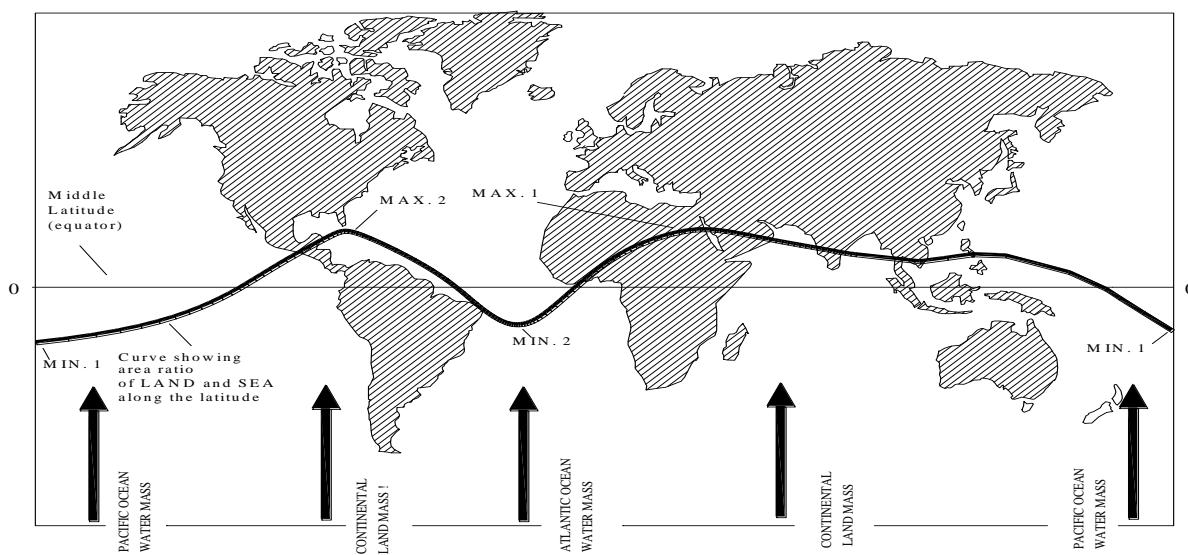


Fig. 5.1.4 THE NATURE OF VARIATION OF SOLAR RADIATION FALLING ON LAND AND SEA AS A FUNCTION OF LOCAL NOON

To understand the effect of land and sea distribution on the Earth current, we may now examine different typical cases resulting from specific orientation of the surface of the Earth towards the Sun. Suppose at any given instant the sea (say the Atlantic Ocean) orient towards the Sun. In this orientation the sea surface receives more solar radiation than the land surface. The charge potential of Atlantic Ocean will reach a maximum and due to good charge conductivity of sea water the charge potential of the entire sea will increase to a maximum value. Once again when the Pacific Ocean faces the sun, the charge potential of the entire sea will have another maximum value. On the other hand, when the American continental land is exposed to the sun light the charge potential of the sea as a whole fall to a minimum value. And again, when the rest of the continents (Asia, Africa, Europe, Japan and Australia etc.) as one integrated land surface face the Sun, the sea as a whole also reaches another minimum potential. The



magnitude of Earth current at any location and time being a function of potential difference between the said location and the nearest sea, exhibits identical fluctuation in the magnitude of the earth current during the hours of the day. The characteristic spread of the sea along the longitude having twice maximum and twice minimum rightly explains the world-wide nature of variation of the earth current having twice maximum and twice minimum as revealed in the earth current hodograph.

The shape of the Earth and its motions allows the equatorial zone to receive more solar radiation than the polar zones. This makes the equatorial zone to remain at a higher potential than the polar zones. Due to this potential difference, charge flow also takes place from equatorial zone towards North and South poles. The orientation of the axis of the Earth with respect to the Sun changes with time. During summer in the Northern hemisphere, the North Pole comes closer to the Sun where the solar radiations are more normal to the surface and the radiation intensity in Northern hemisphere increases. In the similar manner during the summer in the Southern hemisphere, the intensity of solar radiation increases in Southern hemisphere. The changes in the intensity of solar radiation during the change of season causes a periodic change in the potential structure and hence produces a corresponding change in the earth current pattern responding to the season change.

The Earth current can be easily correlated to the terrestrial disturbances in the ionosphere such as ring currents, current across ionospheric layers (auroras), change in geomagnetism, occurrence of polar lights, and solar disturbances like solar flare, sunspot number etc.. Since all the above phenomena is primarily a function of solar radiation, the fluctuation in solar radiation during the solar flare, variation in sunspot number etc. contribute to simultaneous changes in the above electrodynamic features. The cause of disturbance being same for all the above cases, the electrical phenomena is bound to bear a correlation. While observing any two simultaneous events occurring in the atmosphere and on the surface of the Earth it may not be always proper to attribute the cause of one to the other because, there could be an extraneous cause common to both the observed events.

The earth current pattern also responds to lunar cycle. The size of the Moon is small compared to the planets in the solar system, but due to closer proximity of the Earth, the Moon has a significant effect on the earth current. The average charge state of the Moon is negative with respect to the Earth. But due to slow rotation of the Moon with respect to the Sun, there is a great difference in the charge states of the bright and dark surfaces of the Moon. Due to long time exposure to Sun light, the bright surface of the Moon remains at a higher potential than the average charge state of the surface of the Moon and the Earth. The dark surface of the Moon remains at a lower potential than that of the bright surface. Like the effect of the Sun, the Moon



also produces a significant charge polarisation on the surface of the Earth. It further influences the charge state of the surface of the Earth by its characteristic reflection of the Sun light and the low temperature thermal radiation from the dark side. The reflected Sun light from the Moon falling on the surface of the Earth increases its charge potential and the low temperature thermal radiation falling on the surface of the Earth lowers the charge state of the surface of the Earth. In other words, the surface of the Earth, facing the waxing moon get positively charged and when it faces the waning moon gets negatively charged due to typical radiation from the Moon. The waxing and the waning phases of the Moon take place in a periodic manner. Therefore, the Earth current has a distinct component attributable to the effect of the Moon. Due to the effect of the waxing Moon and the waning Moon, the lunar influence on the Earth current have a variation of double period as expected. The intensity of radiation from Moon being weaker, the lunar component of the Earth current is weaker (one fifth the solar component). The tidal effect on sea water can be better analysed by the effect of charge variation on the surface of the Earth due to the Moon.

The analysis of the vertical Earth current is different from the horizontal earth current discussed above. The topographical contour has a significant feature in the terrestrial thermal radiation. The charge loss is more for mountains than the planes due to large surface area per unit solid angle. The charge loss due to thermal radiation is further increased by loss of positive charge from sharp mountain peaks due to corona discharge. Due to greater loss of positive charge by thermal radiation and corona discharge at mountain tops, a constant charge flow takes place from the base of the mountain to the top of the mountain. This causes the vertical Earth current.

This article is a part of the original work published in the book “Planetary electrodynamics-II”, Volume-2 of the series “Dynamics of universe; interplay of matter, space and charge”, 2000 by the same author.

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