A FURTHER STUDY OF ATMOSPHERICS DURING THE MONSOON PERIOD

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Introduction

IN a previous paper I explained that atmospheric activity curves show certain distinctive features during the period of the S.W. (or summer) Monsoon. It was also shown that with the aid of these curves, the formation of a meteorological depression in the Bay of Bengal, its movement inland, and finally its weakening and disappearance could be followed. The curves further show that with the withdrawal of the monsoon, heat thunderstorms which occur mainly in the afternoons become more pronounced.

During the year 1941, the S.W. Monsoon withdrew from the country by about the end of September and the N.E. Monsoon later established itself. The present paper discusses with the aid of data collected in 1941, the characteristics of atmospheric activity of the period (1) between the withdrawal of the S.W. Monsoon and the setting in of the N.E. Monsoon and (2) during the period of the N.E. (or winter) Monsoon.

(1) *Atmospherics during the period of transition*

As typical instances of the atmospheric activity of this period, the atmospheric activity curves from the 1st to the 5th October 1941, will be considered in relation to the weather charts of the same period.

The atmospheric activity curves are given in Fig. 1. The peaks of activity in the figure may be divided into two groups, (i) peaks K, L and M of early morning activity and (ii) peaks A, B and C of atmospheric activity in the evening and early night. These two groups will be discussed separately.

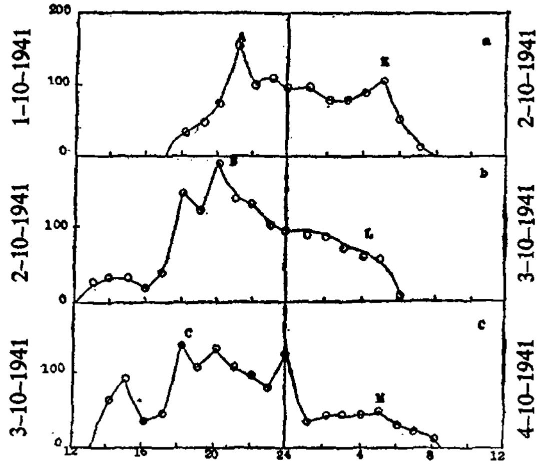
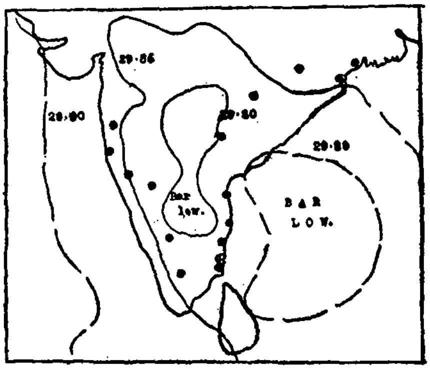
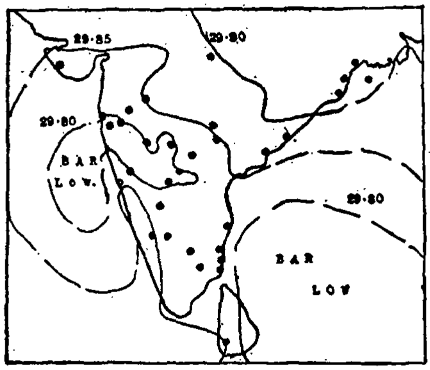


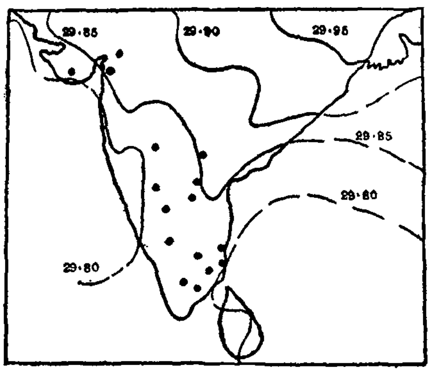
FIG. 1. Atmospheric Activity curves relating to the period of transition from the Summer to the Winter Monsoon



2 (*a*). 2-10-1941. At 8 hours.



2 (*b*). 3-10-1941. At 8 hours.



2 (c). 4-10-1941. At 8 hours.

FIGS. 2*a*, 2*b* and 2*c*. Weather charts relating to the period of transition from the Summer to the Winter Monsoon

● Indicates places from which thunderstorms have been reported during the previous 24 hours.

⊕ Indicates the position of the University Laboratories at Annamalainagar.

Peaks K, L and M.—The weather charts relating to this period are given in Fig. 2. Figs. 2*a*, 2*b* and 2*c* show the distribution of isobars at 8 hours on the 2nd, 3rd and 4th October respectively. On the 2nd a depression appeared in the Bay of Bengal close to the coast. By the morning of the 3rd this region of low pressure became diffuse. By the 4th this became more diffuse and unimportant.

It was pointed out (1943) in a previous paper that the formation of low pressure regions on the sea is associated with observed atmospheric activity in the early mornings. The peak K on the morning of the 2nd may therefore be associated with the low pressure region in the Bay of Bengal in Fig. 2*b*. We notice further that as the low pressure region in the Bay of Bengal becomes more and more diffuse the atmospheric activity represented by L and M decreases. Thus the occurrence and variation of early morning activity represented by peaks K, L and M can without doubt be ascribed to the low pressure region in the Bay of Bengal.

Peaks A, B and C.—Taking next the atmospheric activity in the early night, it must be remembered that during the period of the summer monsoon, large peaks of activity appeared in the early night only when a depression which had formed in the Bay of Bengal crossed the coast and moved inland. The peaks A, B and C resemble peaks of activity which accompanied the movement inland of the depression. In the present case, however, as is evident from the weather reports in Fig. 2, the depression that formed in the Bay of Bengal on the 2nd remained practically in its original position and became unimportant by the 4th. The peaks of atmospheric activity A, B and C cannot therefore be attributed to the effect of this depression.

Fig. 2 further shows that during the period between the 1st and 4th October, a diffuse low pressure area moved across the peninsula from east to west. It was over the peninsula on the 2nd and was off the west coast of India on the 4th. This 'low' over the peninsula became regularly intensified in the afternoon as can be seen from an examination of the weather charts giving the distribution of isobars at 17 hours on these days. (The charts showing this distribution are not reproduced.) This intensification of the 'Low' over the peninsula in the afternoons which is a regular feature of the pressure distribution in the non-monsoon months brings about conditions favourable for thunderstorm activity and for the generation of atmospherics associated with such activity. The peaks A, B and C are the effects of this intensification of the low over the peninsula.

The differences in the appearances of the peaks A, B and C may be explained by a detailed study of the thunderstorm activity of the period.

The regions from which thunderstorm activity is reported in the daily weather reports on these days are indicated by black dots on the weather charts. These reports of the thunderstorm activity refer to the previous twenty-four hours and do not give any indication of the time of the day at which these thunderstorms were active. But a study of a large number of atmospheric activity curves along with the related reports of thunderstorms has shown that there is a greater probability of thunderstorm activity along the coast line, occurring in the later part of the night, specially when a low pressure region exists on the sea and close to the coast. It would in this connection be extremely useful to analyse the actual times of occurrence of thunderstorms. This could not however be carried out for want of necessary data.

It was pointed out in an earlier paper (1943) that if thunderstorms are reported from a large number of areas, it is very unlikely that all these centres are active at the same time. The activity at one centre may be on the decline while that at another is reaching a maximum. Thus data on atmospherics collected from one observing station which cannot distinguish between atmospherics coming from various centres, is likely to show certain characteristic features. If only one narrow region is affected there will be a definite rate of increase of atmospheric activity, which will reach a maximum terminating in a peak, and after which there will be a regular decline resulting finally in zero activity. The atmospheric activity curve may therefore be expected to give a sharp well-defined peak of activity, the rise and decline of activity being very steep. If during a certain period, a large number of centres are active, assuming that the maximum activities at every centre do not necessarily coincide in time, the atmospheric activity curves will show large activity for a considerable time and well-defined peaks are not likely to be observed.

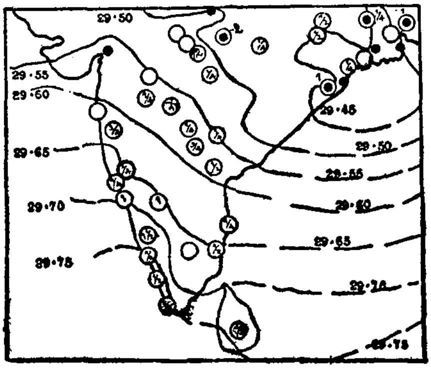
The low pressure areas on the evenings of the 1st and 2nd are concentrated into a narrow region while that on the 3rd is over a very large region. The areas from which thunderstorm activity is reported lie on the outskirts of the region of low pressure. It is no wonder therefore, that atmospheric activity in the evenings and early night shows sharp peaks like A and B as on the 1st and 2nd, while on the 3rd atmospheric activity at a large value continued from 18 to 24 hours and there are three peaks instead of one.

Thus during the period of transition large peaks of activity are observed in the evenings and the early night. This activity is governed mainly by the low pressure regions which develop in the centre of the peninsula and intensify by the evening each day during this period. Atmospheric activity in the later part of the night is on a small scale.

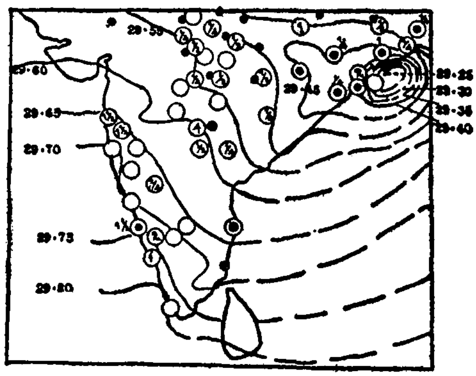
(2) *Atmospherics during the period of the Winter Monsoon*

Several observers have noticed that atmospheric activity during the winter months is on a much smaller scale than in the warmer months. One of the earliest of these is Jackson (1902) who noticed that Atmospherics are more frequent in summer and autumn than in winter and spring. Later, Wolf (1922) found that while during the warm half year atmospherics developed on the appearance of a new depression and disappeared on its filling up, no such relation could be noticed in winter. He says that even thunderstorms failed to give a notable increase in Atmospheric disturbance in winter. Watt (*Nature*, Vol. 127) found that the predominant source of the world's supply of Atmospherics lies in a region of summer afternoon.

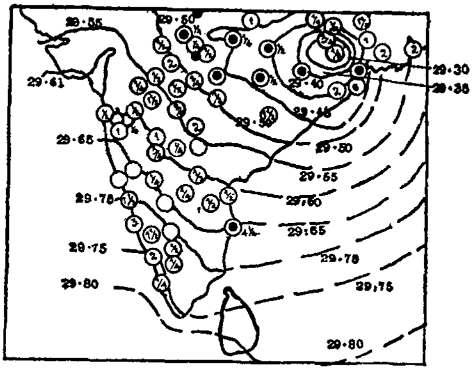
These statements are based on observations in temperate climates. The present paper deals with observations recorded at Annamalainagar, from



3 (*a*). 7–8–1941. At 8 hours.



3 (*b*). 8–8–1941. At 8 hours.



3 (*c*). 9–8–1941. At 8 hours.

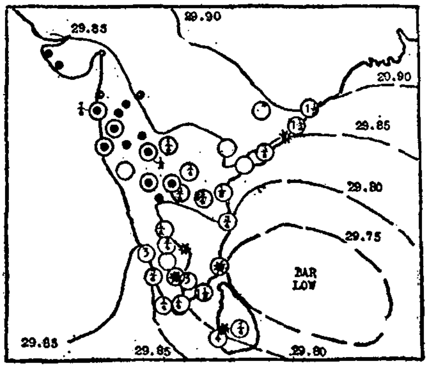
FIGS. 3*a*, 3*b* and 3*c*. Weather charts relating to the period 7th to 10th August 1941 during the Summer Monsoon

○ Indicates places from which rainfall is reported, the amount of rainfall during the previous 24 hours being indicated by the numbers inside the circles.

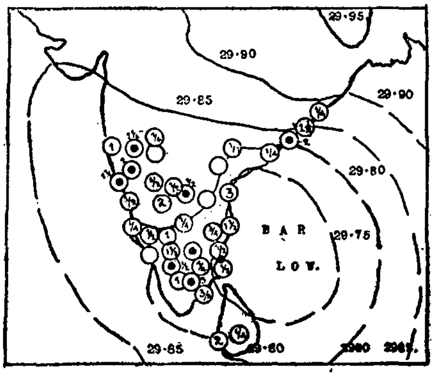
● Indicates places from which thunderstorms during the previous 24 hours have been reported.

October to December 1941 during the period of the winter monsoon. A study of atmospheric activity during this period shows no regular features of the type found in the period of the summer monsoon, and described by me in an earlier paper. I propose to discuss in this paper the probable causes for the striking difference noticed in the behaviour of Atmospherics during the two periods.

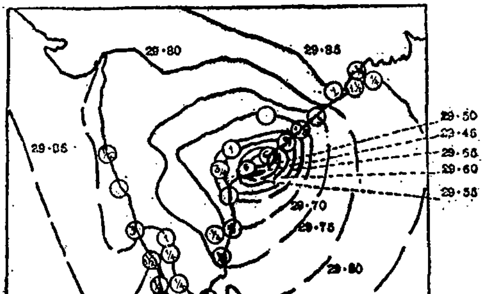
Two sets of weather charts, taken from the Indian Daily Weather Reports, are redrawn in Figs. 3 and 4. The first set refers to the peiiod 7th–10th



4 (*a*). 5–10–1941. At 8 hours.



4 (*b*). 6–10–1941. At 8 hours.



4 (*c*). 7–10–1941. At 8 hours.

FIGS. 4*a*, 4*b* and 4*c*. The weather charts relating to the period 3rd to 8th October 1941 during the Winter Monsoon

O Indicates places from which rainfall is reported, the amount of rainfall during the previous 24 hours being indicated by numbers inside the circles.

Indicates places from which thunderstorms during the previous 24 hours have been reported.

* Indicates areas where thunderstorm activity attributable to the depression in the Bay of Bengal has occurred.

August 1941, during the summer monsoon and the other to the period 3rd–8th October 1941, the beginning of the North East Monsoon.

On these charts the circles indicate the regions from which rainfall is reported, during the previous 24 hours, the actual amount of rainfall being indicated by the numbers inside the circles. According to the convention followed in the mapping out of these charts rain less than ·09″ is neglected. A blank circle indicates rainfall between ·10″ – ·17″.

$\frac{1}{4}$ – ·18″ to ·37″;
$\frac{1}{2}$ – ·38″ to ·87″;
$\frac{3}{4}$ – ·68″ to ·87″;
1 – ·88″ to 1·24″;
$1\frac{1}{2}$ – 1·25″ to 1·74″;
2 – 1·75″ to 2·50″;
3 – 2·51″ to 3·49″, etc.

Weather charts in Figs. 3 *and* 4.—The charts refer to two similar cyclonic storms, one during the S.W. Monsoon and the other during the N.E. Monsoon. In their wake they brought considerable rain to the regions affected, *viz.*, Bengal and Orissa in the first case and S.E. Madras in the second case. In this respect therefore the two cyclonic storms are very similar.

Thunderstorm activity during these periods.—If we compare the thunderstorm activities during these periods we find a striking contrast. Areas from which thunderstorms are reported during the previous 24 hours are indicated by black dots in the weather charts. It is evident from Figs. 3*a* and 3*b*, that the deepening of the depression into a cyclonic storm is followed by increased thunderstorm activity. Thunderstorms are reported from a large number of areas and their positions give an indication of the probable direction of travel of the cyclone. In Fig. 3*c*, we find that as the depression slowly fills up thunderstorm activity is again on the decrease.

It will be clear from the above that thunderstorm activity increases with the deepening of the depression. The position of the areas of thunderstorm activity is mainly governed by the region of low pressure and the activity becomes feeble as the low pressure region fills up.

In Fig. 4*a*, we notice thunderstorm activity at certain places in the Peninsula, a large number of areas to the N.W., a few in the south of the Peninsula and a few along the east coast. From Fig. 4*b*, we find that the depression moved nearer the coast line. In striking contrast to what was noticed in the set of charts given in Fig. 3, we find that with the approach of the depression towards land thunderstorm activity is reported from fewer areas and is hence on the decline. In Fig. 4*c*, we find that the intensification of the depression into a cyclonic storm close to the coast between Masulipatam and Cocanada caused widespread heavy rain along the Madras coast and the adjoining districts but no thunderstorms occurred in any of these areas.

Thus we find that thunderstorm activity which increases during the summer monsoon with the intensification of a depression, disappears under similar conditions during the winter monsoon. As most atmospherics orginate in areas of thunderstorm activity, it is no wonder that atmospheric activity during the period of the summar monsoon shows certain regularities, increasing activity being associated with the formation and accentuation of a depression and its decreasing activity with the movement and disappearance of the low pressure region. In the period of the winter monsoon these features are not noticed.

In this connection one other point may also be mentioned. In Fig. 4*a* the presence of a large number of thunderstorm areas might create an impression that thunderstorm activity is very much greater and further that all these might be due to the effect of the depression formed in the Bay of Bengal. A study of the weather charts for the previous two days, *i.e.*, 3rd and 4th, helps us to determine the true effect of the depression in the Bay of Bengal.

On the 2nd October a depression in the Bay was accompanied by a region of low pressure in the central region of the Peninsula. The chart for this day is given as Fig. 2*b* and thunderstorms were reported from areas lying on the coast line on either side of the land depression.

Judging from the way in which the areas of thunderstorm activity appear and disappear during the three days, 2nd, 3rd and 4th October, it appears as though the activity in the N.W. region of the Peninsula may be attributed to the depression on land noticed on the 4th and to the depression in the Arabian Sea (Fig. 2*c*). We are thus left with a few areas only, areas which showed no variation with the appearance or disappearance of the depression in the Arabian sea, or the depression on land. These areas are indicated in the figure thus✵. It will thus be evident that even when thunderstorm activity is reported and atmospherics are recorded at the observing station, they arise only from small isolated areas and that the total atmospheric activity itself is small.

One example may be given to show how small the atmospheric activity is when it exists. A deep depression formed in the Bay of Bengal on the 30th of November intensified into a cyclonic depression on the 1st December, became severe and passed inland by the night of the 2nd. Later this moved right across the Peninsula and entered into the Arabian Sea by the 4th and became unimportant by the 6th.

This particular example is of special interest as the cyclonic storm passed almost over the observing station. If there had been atmospheric activity of the intensity usually met with in the summer monsoon period, no record could have been obtained, as the recording equipment would have been upset on account of the powerful impulses given to the galvanometer. Although a few atmospherics were actually recorded during this period, the atmospheric activity must be judged as being of negligible amount, the little activity that was observed being attributable to very feeble isolated lightning flashes possibly occurring far above the monsoon clouds, invisible from the ground and unaccompanied by thunder. As the convention in the Indian Meteorological Department is that thunderstorm should be repoited only when thunder is heard with or without precipitation, the Weather Reports do not mention any thunderstorm during this period.

Discussion

As stated already during the period of the Summer monsoon thunderstorm activity and the associated Atmospheric activity are on a large scale, while during the Winter monsoon they are of negligible amount. It was also pointed out that atmospheric activity is intimately connected with meteorological depressions, and that the study of the variation of Atmospheric activity from hour to hour and day to day enables us to follow the various stages in the formation, accentuation, movement inland and the subsequent filling up of the meteorological depressions that originate in the Bay of Bengal during this period.

It may be considered surprising that there is only a small amount of thunderstorm and Atmospheric activity during the period of the winter monsoon. Further, as has been already pointed out, the little Atmospheric activity that does exist, becomes feeble on the intensification of a depression.

Brunt (1934) considers the greater frequency and intensity of the meteorological depressions in Europe in winter as due to the larger differences of temperature between the pole and the equator in winter than in summer. The reason for the feeble thunderstorm activity during this period may be understood from a discussion of the various features involved in the formation of depressions and the generation of thunderstorm and the associated Atmospheic activity.

The most important of these factors is Solar Radiation. The effect of the sun in bringing about conditions favourable for the display of energy automatically in the atmosphere in the form of a thunderstorm is described by Napier Shaw and Captain Douglas. According to Napier Shaw (1930) the first condition to be satisfied is the existence of a state of liability in the atmosphere caused by the establishment of a thick layer in convective equilibrium. Another condition is the provision at the right moment, of a sufficient quantity of air saturated with water vapour. Both these conditions are governed by the effect of Solar Radiation.

Convection on a large scale in air of a high degree of humidity is essential for the production of towering cumulus clouds whose base, according to Captain Douglas (1923) is usually between 5,000 to 6,000 feet, in severe thunderstorms, and whose tops attain 20,000 feet in summer and 15,000 feet in winter. Captain Douglas also states that the existence of at least one damp layer as low as 6,000 feet appears to be a necessary condition for the development of thunderstorms.

The electrification of thunderclouds is explained by the well-known theories of Wilson and Simpson. The mechanism suggested by Wilson as the cause of opposite charges on large and small drops inside a thundercloud depends upon the presence in the cloud of a number of slow ions. In the earlier stages of development of a thundercloud these may arise from natural sources, but later on they will be supplied in numerous numbers by brush discharges from water drops (Macky, 1933) drawn out by the field into pointed forms (Schonland, 1932). According to Simpson (1927) the generation of electricity is a consequence of the disruption of rain drops when caught in a vigorous convection current. A water drop with a radius of more than 0·25 cm. becomes flattened out and unstable when it falls through the air with the result that it breaks up into a number of smaller drops. Since the terminal velocity of a falling drop with a radius of 0·25 cm. is 8 metres per second, it follows that no drop of water can ever fall downward through an ascending current of air whose vertical velocity exceeds 8 metres per second.

Formation of a meteorological depression.—Convection again plays an important part in the formation of depressions. The formation of a depression involves the removal of large amounts of air for the fall of pressure. All theories put forward for explaining the formation of a depression are based on the existence of horizontal differences of temperature and the displacement of warm air by cold air. According to Brunt (1934) the most obvious method of removal of air is by means of a convection current, produced by inequalities of temperature, or water vapour content or by the effect of surface discontinuity. If warm damp air is set in motion by its buoyancy the continuance of the upward motion as an effect of the condensation of moisture is easily understood. Such an ascending current has a scouring effect on the environment, the process being aptly described as 'eviction of air'.

It is thus seen from the above that vigorous convection plays a most important role in the formation of cumulus clouds, in the generation of electrical charges in thunderclouds and also in the formation of depressions. Convection is dependent on Solar Radiation and therefore it would be instructive to consider how these effects are modified by the varying amounts of solar radiation received at various parts of the globe and at the various seasons.

It is well known that thunderstorms are more frequent and more violent in the tropics. Simpson (1927) attributes this in the first place, to the larger water vapour content of the air in the tropics which provides the greater energy for driving the currents upwards to much greater heights. Secondly, the height at which the freezing point is reached is much greater and finally the stratosphere is so much higher that there is more vertical room in which the thunderstorms can develop. By an extension of the same argument, the cause of the smaller thunderstorm activity during the period of the winter monsoon as compared with that of the summer monsoon may be traced to the lower temperatures during the former period.

There seems to be no doubt that convection is quite vigorous during the period of the winter monsoon. Napier Shaw (1930) points out that rainfall is the best index of convection and that the absence of rainfall is equally good evidence of the absence of any persistent ascending current. The large amount of rainfall that occurs on the outskirts of the depressions formed during the period of the monsoon, in the Bay of Bengal, is sufficient evidence of the existence of convection on a large scale. But there is no thunderstorm activity in spite of the large convection.

Brunt (1934) points out that in addition to the mechanism that gives rise to vertical convection in any region where a lowering of pressure is taking place, there must be present some mechanism for removing the air that has ascended. Otherwise this vertical motion cannot continue for any length of time. The simplest mechanism that may be thought of is an upper current whose direction differs from that of the current in the lower troposphere. Brunt takes the outward motion of cirrus clouds from the centre of a cyclonic system as evidence of the existence of such a current. In the absence of some means of removal of the evicted air a thunderstorm is a more likely occurrence than a cyclonic system. The absence of thunderstorm activity during the winter monsoon period even when vigorous convection is taking place may probably be due to the causes enumerated above.

Finally there is also the conductivity of the atmosphere. Considering the smaller space, in which thunderstorms during the winter may develop, the intensity of the depressions formed during the period and the large amount of rainfall accompanying the formation of cyclonic systems, it may be expected that the conductivity of the atmosphere may rise to large amounts and give rise to leakage effects. Schonland (1932) from a study of the recovery curves of a thundercloud after a discharge showed that the electrical energy generated by the storm is only partially employed in the feeding of the flashes. At the moment just before the discharge most of the power of the machine is expended in overcoming various leakage effects. If the conductivity of the atmosphere becomes very large, it may happen that the potential of the thunderclouds may never reach the sparking value.

A review of recent work on Atmospherics in Nature (1936) states that it is now generally agreed that the majority of atmospherics encountered in Radio Communication originate in lightning flashes. When the storm is close to the receiver it is possible to identify the stronger atmospherics with the neighbouring flashes. It is therefore quite easy to understand that if the potential of the thunderclouds does not attain the sparking value no lightning flashes can occur and hence the amount of Atmospheric activity must be very small indeed.

Some observations on the variation of Atmospheric activity with precipitation and conductivity lend support to the above view. Wiedenhoff (1921) found that atmospheric activity was at a minimum with maximum conductivity at a moderate height with overcast sky, with maximum relative humidity and minimum temperature. Rothe (1921) found that atmospherics produced by storm clouds cease as soon as uniform rain starts.

Thus the striking difference in the variation of Atmospheric activity in the periods of the Summer and the Winter Monsoon may be traced to (i) the lower temperature, (ii) the smaller height available for the development of thunderstorm activity, (iii) the operation of a mechanism by which the ascending current of air is removed by means of an upper air current and (iv) the larger leakage effects that are likely to prevent the charges in the cloud building up to the sparking value.

Summary

The paper discusses the characteristics of Atmospheric Activity during (i) the period of transition from the South West (or the summer) monsoon to the North East (or the Winter) monsoon, and (ii) the North East (or the Winter) monsoon.

During the period of transition large peaks of activity are observed in the evenings and the early night. This activity appears to be governed mainly by the pressure regions which develop in the centre of the Peninsula by

the evening each day during this period. Activity in the later part of the night is on a small scale.

It was pointed out in a previous paper that during the summer monsoon, unsettled conditions in the Bay of Bengal give rise to continuous Atmospheric Activity throughout the night; the formation of a depression is accompanied by large atmospheric activity in the early mornings; the movement of the depression inland by an increase in early night activity and the disappearance of early morning activity. It was further shown that the various stages in the formation, movement inland and finally the filling up of the depression could be followed with the aid of the Atmospheric Activity curves.

During the period of the North East Monsoon, however, there is a striking contrast. With the setting in of the monsoon the atmospheric activity becomes very feeble. Further, the little activity that does occasionally exist disappears on the accentuation of depressions that are formed in the Bay of Bengal and the Arabian Sea during this period.

In the later part of the paper the probable causes for this difference in behaviour are discussed. It is suggested that this difference in behaviour may be due to (i) the lower temperatures, (ii) the smaller height available for the development of thunderstorm activity, (iii) the operation of a mechanism by which the ascending current of air is removed by an upper air current, and (iv) the larger leakage effects that are likely to prevent the charges in the cloud from building up to the sparking value.

In conclusion I have much pleasure in expressing my thanks to Dr. S. Ramachadra Rao, D.SC. (London), Professor of Physics, for valuable guidance and helpful criticism.

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