Height Variations in the Concentration of Ions Near the Ground During Quiet Summer Nights at Uppsala

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Abstract

Results of measurements of the concentration of small- and large-ions at different heights near the ground during quiet summer nights at Uppsala are given. Characteristic shapes for the variation of the concentration of ions are illustrated. At the ground the concentration of small ions increases more than at higher levels, where also an enhanced content of small ions can be observed during the stated weather conditions. The number of large ions descreases after sunset reaching a minimum at sunrise, after sunrise a comparatively rapid increase follows. It seems that the concentration of large ions near the ground is actually a little below that at the higher levels. Preliminary explanations of the variations are outlined.

Introduction

We have developed the concept that some of the variations of the ionic density observed by us in the summer of 1949 (17) were caused by the accumulation near the ground of emanation exhaled from the soil, and consequently also by its decay products, under certain meteorological conditions in which a minimal mixing of air takes place (18), (19). A detailed investigation of the variations of the ionic density, under meteorological conditions which might favour the accumulation of emanation near the ground, was carried out at the Institute for High Tension Research at Uppsala in the summer of 1950; the ionic density was measured at different levels above the ground in order to obtain an insight into the mixing conditions prevailing. Measurements of elements characteristic of the electrical properties of atmospheric air at different levels are not very numerous, though they may be of great importance. Investigations of the potential-gradient at three different levels have been carried out by DAUNDERER (6) and by NORINDER (15). BROWN (4) has measured the space-charge in atmospheric air at different levels near the ground. BECKER (1) and DEIJ (7) have measured the content of emanation at two levels. Conductivity of the air, mainly due to small ions, in the lowest levels of the atmosphere has been measured at different heights by HOGG (10). The vertical distribution of atmospheric condensation nuclei has been measured by YUNKER (24) at two levels.

We have further investigated the electrical elements of atmospheric air near the ground at different levels by measurements of the ionic density. In this manner we hope to gain an insight into the matter of ionization processes near the ground and their correlation with the conditions of mixing of air there.

Arrangement of the measurements

To be able to measure the ionic density at different levels above the ground a special device was built by which air was sucked from three levels above the ground ($h_1 = 0.1$, 0.05 m, $h_2 = 0.5$, 0.25 m, $h_3 = 2.1$ m). The ionic density of the air sucked from these different levels was measured with the ion-counters used during the preceding measurements at the Institute (16), (17), (23). Small ions of both polarities were measured with two reconstructed EBERT ion-counters (16) and the positive large ions with an ISRAËL large-ion counter (23). Some difficulties arose during the measurements. At sunset insects were sucked into the EBERT counters and remained on the insulators of the electrometers. The apparatus could be cleaned by compressed air or by dissembly. Another kind of difficulty was encountered with the large-ion counter during this series of measurements; the insulation losses of the counter were variable, increasing abnormally during the night and diminishing again during the early morning hours. It seemed at first that measurements of the large ions were impossible because of the above mentioned abnormal irregularity in the deterioration of the insulation. It may be supposed that the most probable cause for the observed diminution of the insulation was a radioactive deposit, precipitated on the condensers of the counter during the aspiration of air through it. If the number of large ions must be measured with a large-ion counter in the manner used by us during selected summer nights when an enhanced quantity of active deposit may be expected, especial attention must be paid to the determination of the fictive insulation "losses" of the apparatus as a function of the time of aspiration and of the time lapse after the interruption of aspiration.

Results of measurements

The measurements of the ionic density were carried out during selected nights when conditions could be expected to be favourable for the accumulation of emanation because of stratification of the air near the ground. The nights selected were without clouds and windless. Variations of the measured concentration of small and large ions during some of the nights selected are shown in figs. 1, 2, 3, 4, and 5. The positive ionic density is denoted by the full line (———) and the negative ionic density by the dashed line (- - - - -). Values corresponding to different levels are denoted by different designations as shown in the figures. The noted time is Central-European. The temperature given in the figures may be regarded as a factor, characteristic of the meteorological conditions prevailing during the observation periods.

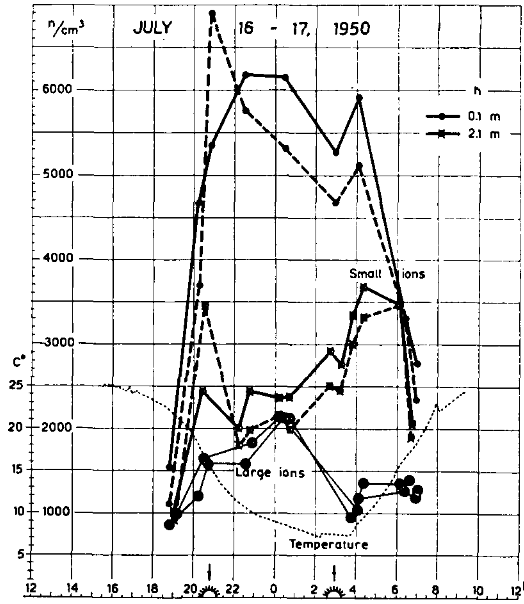

Fig. 1. Variation of concentration of ions at two levels on July 16—17, 1950; ——— positive small ions, - - - - - negative small ions, ——— positive large ions.

Small ions. From an examination of the variations shown in figs. 1, 2, and 4 two superposed kinds of variation of the concentration of small ions can be identified:

(1) Variations of a longer time scale which extend over the entire observation period, and (2) variations of a shorter time scale with a duration of one to several hours. Variations of still shorter period may exist, but are not detected with the arrangement of measurements used. For a general insight into the basic effect variations of the first kind are of fundamental interest. The variations of a shorter time scale can be regarded as the result of variations in the environmental conditions. The increase of the ionic density at

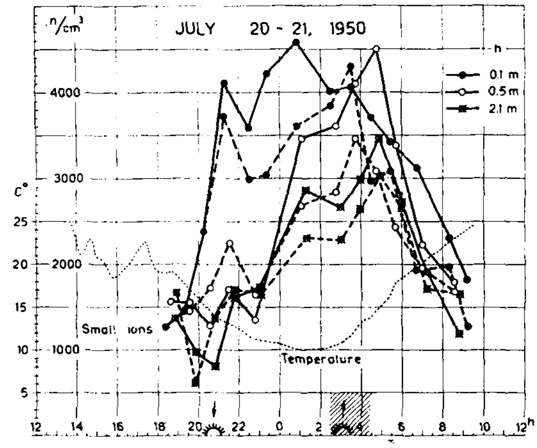

Fig. 2. Variation of concentration of small ions at three levels on July 20—21, 1950; ——— positive small ions, - - - - - negative small ions, |||||||| fog.

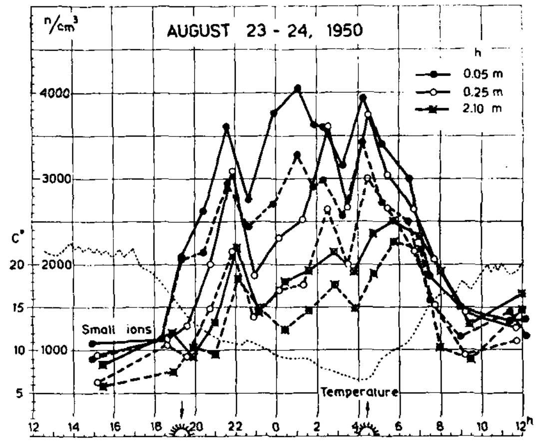

Fig. 4. Variation of concentration of small ions at three levels on August 23—24, 1950; ——— positive small ions, - - - - - negative small ions.

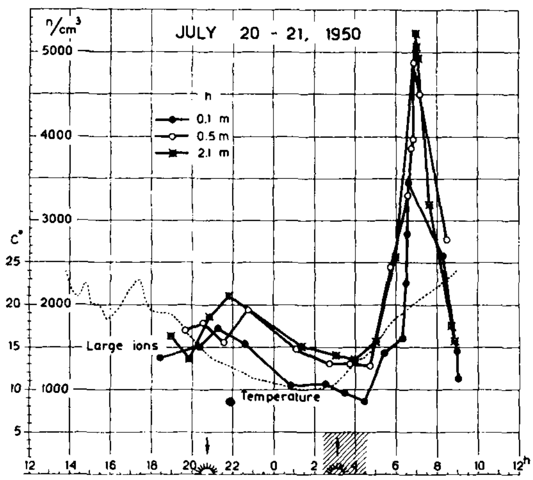

Fig. 3. Variation of concentration of positive large ions at three levels on July 20—21, 1950; |||||||| fog.

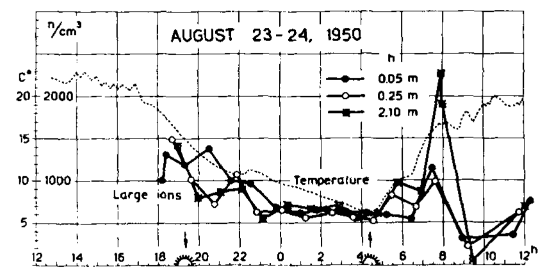

Fig. 5. Variation of concentration of positive large ions at three levels on August 23—24, 1950.

the two higher levels ($h_2 = 0.25$ m and $h_3 = 2.10$ m) at 22^h in fig. 4 can be regarded as an extreme example of such short-period variations. This increase was perhaps caused by air, with a higher content of ions or ion producers, rising locally from the ground. A stronger decrease can be observed at all three levels following the increase of ionic density at the higher levels h_2 and h_3. A similar effect can be observed during the same night between $2^h\,30^m$ and $3^h\,40^m$. In this way the shorter-period variations may be regarded as local disturbances which deform the general course of the effect, and from the study of which it may be possible to determine finer variations of the conditions which favour the basic effect.

Smoothed curves. In order to obtain the undisturbed course of the effect an attempt is made to smooth the curves of the measured trend of the small ions detected, neglecting variations of a shorter time scale. These smoothed curves which may be regarded as idealized trends of the effect are shown in fig. 6.

The shape of the variations of the small ion concentration. The following features of the variation in concentration of small ions during the effect may be pointed out:

(1) At the ground an increase is observed which proceeds very rapidly at sunset; during the night the ionic density remains comparatively high with only a slow decrease until 1—2 hours after sunrise when it decreases rapidly.

(2) At the higher levels an increase also begins at sunset and continues until 2—3 hours after sunrise; after that time a rapid decrease follows.

(3) At higher levels the number of small ions is smaller.

(4) The concentration of positive ions is higher than that of negative ions.

(5) The sudden increase in the concentration of negative ions over the positive ions at the beginning of the increase at sunset (fig. 1) deserves attention. A similar phenomenon was observed also during other series of measurements, especially at higher levels (for example see fig. 2).

(6) In addition to variations of a relatively long time-scale (extending over the entire observation period), variations of a shorter time scale (with a duration of one to several hours) may be observed.

Large ions. As mentioned before, it seemed impossible at first to obtain measurements of the large ions because of the abnormal deterioration of the insulation of the apparatus during the measurements. For the same reason we were unable to determine the spectral composition of large ions with the method used earlier (23). The measurements of large ions during these series were carried out at an adjusted limit mobility $k_* = 2.14 \times 10^{-4}$ cm sec^{-1}: V cm^{-1}. Taking into account the trend of the insulation it was attempted to calculate the variations of the concentration of large ions during the effect. Surprisingly, the trends obtained for the variation of the concentration of large ions were of a characteristic type. Two families of smoothed curves of these variations are shown in fig. 1 using different combinations of the observed curves. The general features of the variations of large ions during the effect are as follows:

(1) A decrease may be noted from sunset to sunrise, when a minimum is reached; after sunrise a comparatively rapid increase follows.

(2) It appears that the concentration of large ions near the ground is really a little lower than that at the higher levels.

The trend of the concentration of large ions is given in fig. 7 unexpectedly exactly; only the height of the maximum after sunrise could not be determined exactly with the data at hand. It must be noted here that by evaluating the trend of the variations of large ions during individual nights and also by the smoothing of the curves shown in fig. 7 every effort was made to suppress the variations; nevertheless a characteristic trend remained.

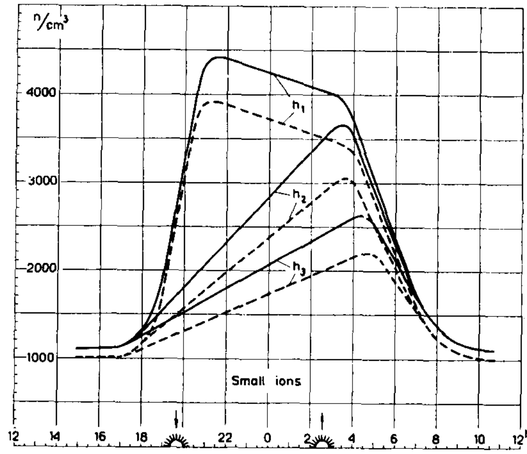

Fig. 6. Idealized trend of the variations of the concentraion of small ions at the ground (h_1), and at two higher levels ($h_2 < h_3$) during quiet summer nights at Uppsala; ——— positive small ions, - - - - - negative small ions.

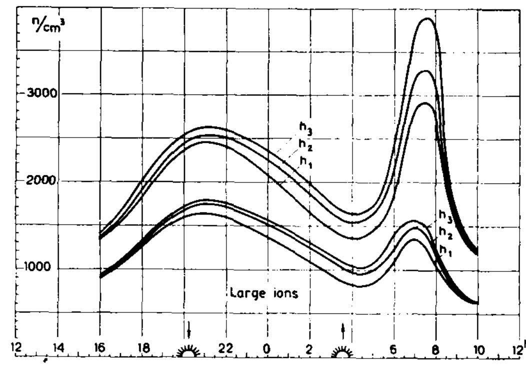

Fig. 7. Idealized trend of the variations of the concentration of positive large ions at the ground (h_1), and at two higher levels ($h_2 < h_3$) during quiet summer nights at Uppsala.

Points to be kept in mind in explaining the variations

We have previously given a preliminary general explanation of the observed variations of the concentration of ions during certain specified weather condition (18), (19). Indications will be given here, of a way by which a more detailed explanation of the whole effect may be obtained. A survey of these subjects will be given later on.

Accumulation of emanation near the ground. The additional ions or the producers of ions necessary to produce the increase of the ionic density could not have been conveyed to the place of observation from another region because the horizontal motion of the air was feeble (in some cases calm prevailed). At the same time the vertical air motion must have been negligibly small, since with a minimum temperature at the ground turbulence must have been almost completely suppressed. The cause of the increased ionic density must be found at the place of observation itself. In our case the most probable prime cause of the increased ionic density might be expected to be the accumulation of emanation exhaled from the soil into the air layers nearest the ground, as shown more detailed in (18), (19). This effect may occur only under certain meteorological conditions under which mixing of the air is suppressed.

Austausch-processes and electrical phenomena in the atmospheric air. The mixing processes in atmospheric air may be considered as *Austausch*-processes — an idea introduced by SCHMIDT (21). Therefore the process of the accumulation of emanation in the layers of air near the ground must be considered as a process stipulated by *Austausch*. Attempts have been made to apply the theory of Austausch to several problems of atmospheric electricity. The distribution of radioactive substances in the free atmosphere has been considered in terms of Austausch by HESS and SCHMIDT (9), SCHMIDT (22), PRIEBSCH (20), and LETTAU (13). Variations of the potential-gradient have been considered in terms of Austausch-theory by BROWN (5), FRANKE (8), ISRAËL (11), and of the electrode-effect by LETTAU (13).

Our problem of the increase of the concentration of small ions near the ground under weather conditions, during which the accumulation of emanation exhaled from the soil and stratification of ions near the ground may be expected, is more complicated, but it is evident that this problem must be considered as one stipulated by *Austausch*. Consideration of the individual processes which may be of importance to the whole problem could not give us results of full certainty because of the lack of several data necessary for the calculations (for example, the combination processes between small- and large ions and nuclei, the recombination processes in the track of an α-particle etc.). Even so, conclusions of interest could be obtained by such considerations.

Some considerations concerning the trend of the number of large ions. In order to show the perspectives which may appear through a more detailed consideration of the phenomena described in this article we will here mention some events which may have a connection with the observed variations of large ions.

The minimum prior to sunrise and the enormous increase of the concentration of large ions after sunrise was at first a surprise to us. But we have taken into consideration facts known about the diurnal variation of condensation nuclei; large ions may be considered as a fraction of the condensation nuclei. Unfortunately, "in spite of the numerous observations of nuclei, there is not yet a definite relationship established between time of day and number of nuclei" as stated LANDSBERG (12). BRADBURY and MEURON (3) have stated that "The diurnal variation in nuclei-density shows a definite maximum in the forenoon and in the evening with a *pronounced minimum prior to sunrise* and a midday minimum of lesser extent. *Such a variation might be expected in the normal daily convective cycle.*" (Underlined by us.) Characteristics similar to those found by BRADBURY and MEURON for the ground level have been established by YUNKER (24) for a level 50 cm and another 20 m above the ground. It is seen that the nuclei-density at the 20-metre level is on the whole higher than that at the ground. That the concentration of nuclei at night may be much smaller than the day average is also shown by NOLAN and TEDDE (14). A theoretical consideration of the trend of the concentration of nuclei is given by FRANKE (8) in terms of Austauschprocesses. The course of the concentration of nuclei during night-hours calculated by FRANKE with a minimum and a higher maximum shows a similarity to the trend of large ions observed by us. We cannot accept in whole the mechanism used by FRANKE, but it appears that a description of the effect observed by us could be given with some modification.

It seems that a detailed investigation of the associate phenomena may give us important information about the events considered here. In addition it could be mentioned here that also variations of sight may contribute to the understanding of our problems. BIELICH and RITSCHL (2) have considered the diminution of sight after sunset and a probable explanation of this effect is given in terms similar to those by which the observed marked diminution of sight 1—2 hours after sunrise during radiation nights is explained.

A more detailed account of the investigation presented here will appear in *Arkiv för Geofysik* published by Kungl. Svenska Vetenskaps-akademien, Stockholm.

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