Variations in the Density of Small-Ions Caused by the Accumulation of Emanation Exhaled from the Soil

By HARALD NORINDER and REINHARDS SIKSNA
Institute of High Tension Research, University of Uppsala

(Manuscript received 24 January 1950)

Abstract

Observations indicate that the density of ions increases during meteorologically undisturbed summer nights. This typical increase is discussed and it is suggested that the probable cause is to be found in the accumulation of emanation exhaled from the ground. The accumulation occurs in weather situations which weaken or suppress convection.

Introduction

It is well known that the density of ions in atmospheric air is highly variable. This fact is shown also by measurements of the variation characteristics of the density of small-ions carried out at the Institute of High Tension Research of the University of Uppsala (NORINDER a. SIKSNA 5, 6). This variability is in part due to the diversity of basic processes which lead to the creation and annihilation of such ions in atmospheric air. It is not always possible to isolate these effects in a clear manner and they are often superimposed. To these processes must be added the fact that the character of the variation of ion-density is dependent also on local environmental factors. It appears in fact possible to state that the ion-density depends quite strongly on certain meteorological factors and on the location selected for such measurements. It is not always possible to state with certainty the character of this dependence, but it is clear that the causes of the variation of the ion-density in atmospheric air cannot be identified until we have succeeded in establishing the undisturbed form of this variation.

In the publications referred to above we have discussed some influences that have been generally accepted by other authors. Certain variations, especially the increase of ion-density, can be explained through the advection of air masses with higher content of ion producers; such air masses may be enriched with producers of ions by travelling great distances over land. The increase of the density of negative ions during rainy weather is possibly caused by the negative charges produced by spraying water. The increase of positive ion-density during a snowstorm may perhaps be explained through the electrification of the snow-particles by collission and shattering.

A series of observations showing decreasing ion-density during winter could perhaps be due to the transformation of small-ions into heavier ones, and this process may be connected with humidity conditions in the air. In the winter measurements no relation between ion-density and air temperature was found. Summarily it can be stated that variations of the ion-density during the winter measurements were mainly determined by certain properties of the air-masses advected, such as content of ion producers, humidity etc.

In this article we will discuss a type of ion-density variation observed by us during the summer of 1949 which is especially typical of certain meteorological conditions.

Variation on the ion-density during undisturbed summer nights

During the first seven days of the uninterrupted series of summer measurements a kind of variation was observed which was regularly repeated, and which could not possibly be explained in terms of air-masses advected from other regions. The form of these variations is as follows:

During the late hours of the afternoon or in the evening the ion-density gradually increases, reaching a maximum value of more than 3 000 n/cm³ at about 4 AM the following morning. During the following 3—7 hours the ion-density decreases to the average diurnal value of c. 1 200—1 500 n/cm³. Such variations of the ion-density are illustrated in fig. 1—8. The positive ion-density is denoted with heavy full lines (—) and the negative ion-density with thick dashes (— — —); the time used is Central-European. In order to indicate the meteorological conditions favourable for this effect some of the meteorological factors are also shown in these figures. The meteorological data were obtained from the Meteorological Institute of Uppsala University. The direction of the wind is indicated at the top of each figure for every hour, but it is marked only at the points of change so that for a particular hour the previous designation is valid if no designation is given. The velocity of the wind (m/sec) is also represented graphically in the figures with thin full lines (——). The cloudiness is represented between the two parallel lines at the top of each figure; for a cloudless sky the space between the lines is left blank, for a clouded sky it is filled. Rain is designated by / / / /. In addition to the ion-density the temperature of the air in °C is given by thin solid lines (——), the water vapor pressure in mm Hg is denoted with thin dashes (— — —), and the relative humidity in % with thin dashes and points (— · — · —).

From the figures it appears that two of these meteorological factors are related to the observed increase of ion-density during night-time. These factors are the temperature of the air and the velocity of the wind. The effects of water vapor will be discussed later. The maximum ion-density very nearly coincides with the minimum temperature. When the ion-density increases the velocity of the wind decreases gradually, and when the ion-density decreases again, the velocity of the wind increases.

It seems most probable that the temperature and the velocity of the air are the factors that are responsible for the variations of ion-density here discussed. From this a probable mechanism for the origin of the increased ion-density observed during the time period under consideration may be deduced. The additional ions necessary to produce the increase of ion-density could not have been conveyed to the place of observation from another region because the horizontal motion of the air is feeble (in some cases calm prevailed). At the same time the vertical air motion must have been negligibly small, since with minimum temperature at the ground turbulence must have been almost completely supressed. After the lowest temperature is reached, as the air again begins to warm up, vertical convection appears mixing results and the ion-density decreases. The cause of the increased ion-density must be found at the place of observation itself.

It is generally accepted that ions in the lower layers of the atmosphere are produced mainly by cosmic rays, by the ionization of air particles through radiation from radioactive substances in the earth and from such ones exhaled from the earth's surface and spread in the atmosphere. In our case the most probable prime cause of the increased ion-density might be expected to be the accumulation in those air layers nearest the surface of emanation exhaled from the soil.

Exhalation of emanation from the soil and its accumulation in the lower layers of the atmosphere

Direct measurements of the exhalation of emanation from the soil have been carried out repeatedly. The first attempt to obtain such measurements was made by EBERT (1), but it was not possible to evaluate his results quantitatively. More exact measurements were carried out by JOLLY and SMYTH (2) and SMYTH

(11) at Dublin and by WRIGHT and SMITH (13) at Manila, but the techniques used were not handy, and much time was required for the measurements. A somewhat different method was used by KOSMATH (3) at Liebenau. An essentially simpler method, similar to the one used by SCHMID (8) to determine the contents of emanation in cellar-rooms, was proposed by HESS, and measurements of soil exhalation using this method have been made by ZUPANCIC (14) at Innsbruck. All the methods listed above have the disadvantage that the emanation is collected over a fairly long time period; thus the results obtained represent averages over a relatively long time interval. With such techniques it is impossible to obtain the diurnal course of the exhaled amount of emanation, even though variations over longer time intervals may be determined. ZUPANCIC has found variations in the exhalation with ratios of 1 : 100. In summer, and at a high ground temperatures, the exhalation reaches a maximum.

The exhaled emanation does not remain in the layers of the atmosphere near the ground, but will generally be spread through the whole atmosphere. An accumulation of the emanation in the lower layers of the atmosphere can appear, however, under certain meteorological conditions. Already WRIGHT and SMITH (12) have observed an increase in the amount of the emanation in the lower layers of the atmosphere at night. The same thing is found by SCHMID (7). MESSERSCHMIDT (4) has shown a strongly marked diurnal variation in the emanation content of the atmosphere. This variation is in opposition to the diurnal variation of temperature.

MESSERSCHMIDT explains the observed maximum in the emanation content of the atmosphere during the morning hours, and the minimum observed in the afternoon in terms of variations in thermal convection in the atmosphere. A decrease of 1° C per 100 m (adiabatic lapse rate) is sufficient to originate vertical convective motion in the air. As the air near the earth's surface is warmed the emanation will be carried up from the ground, and in this way the emanation content decreases until the time of maximum temperature during the afternoon hours. During the gradual cooling after sunset, in the absence of wind, the same air mass will remain near the ground, and will be enriched there by emanation. This state of attains continues until the addition of more surface heat during the following morning produces further convection. On days with strong radiation heating these thermal convection currents may bring warm surface-air to a height of several kilometres. Even on those days with only a small temperature variation, vertical motion of the air can occur, and the ground-air enriched with emanation is thereby removed from the vicinity of the surface.

Application of the proposed mechanism for the accumulation of emanation in explanation of the increase of ion-density during calm summer nights

We shall now attempt to apply the mechanism just discussed for the accumulation of emanation in the lower layers of the atmosphere in explanation of the observed variations of ion-density. As before mentioned, in our case we observe an inverse relationship between the ion-density and the temperature. Also, the velocity of the wind was small or calm when the higher ion-densities were recorded. This was particularly noticeable during the last hours of 10.6 (fig. 1) and the first hours of 11.6 (fig. 2); during this time the velocity of the wind was extremely low, and for a while it was even calm; similar conditions prevailed during the last hours of 12.6 (fig. 3) and the first hours of 13.6 (fig. 4), atlhough we note at midnight an increase in the velocity of the wind which causes a temporary diminution of the ion-density. A similar course of events can be noted on 15.6 (fig. 6) and 16.6 (fig. 7). On 17.6 (fig. 8), on the other hand, conditions are disturbed by rain. Also, the velocity of the wind is greater and, the ion-density is low and without great variations; the small increases in the density of negative ions at 4^h, 11^h, 18^h and 23^h may be explained through the production of negative charges in spraying water. Analogous conditions can be found on other days during our uninterrupted measurement series.

Thus it is shown that during periods of increasing ion-density on calm summer nights the meteorological factors observed favour an accumulation in the surface layers of the emanation exhaled from the soil and therefore

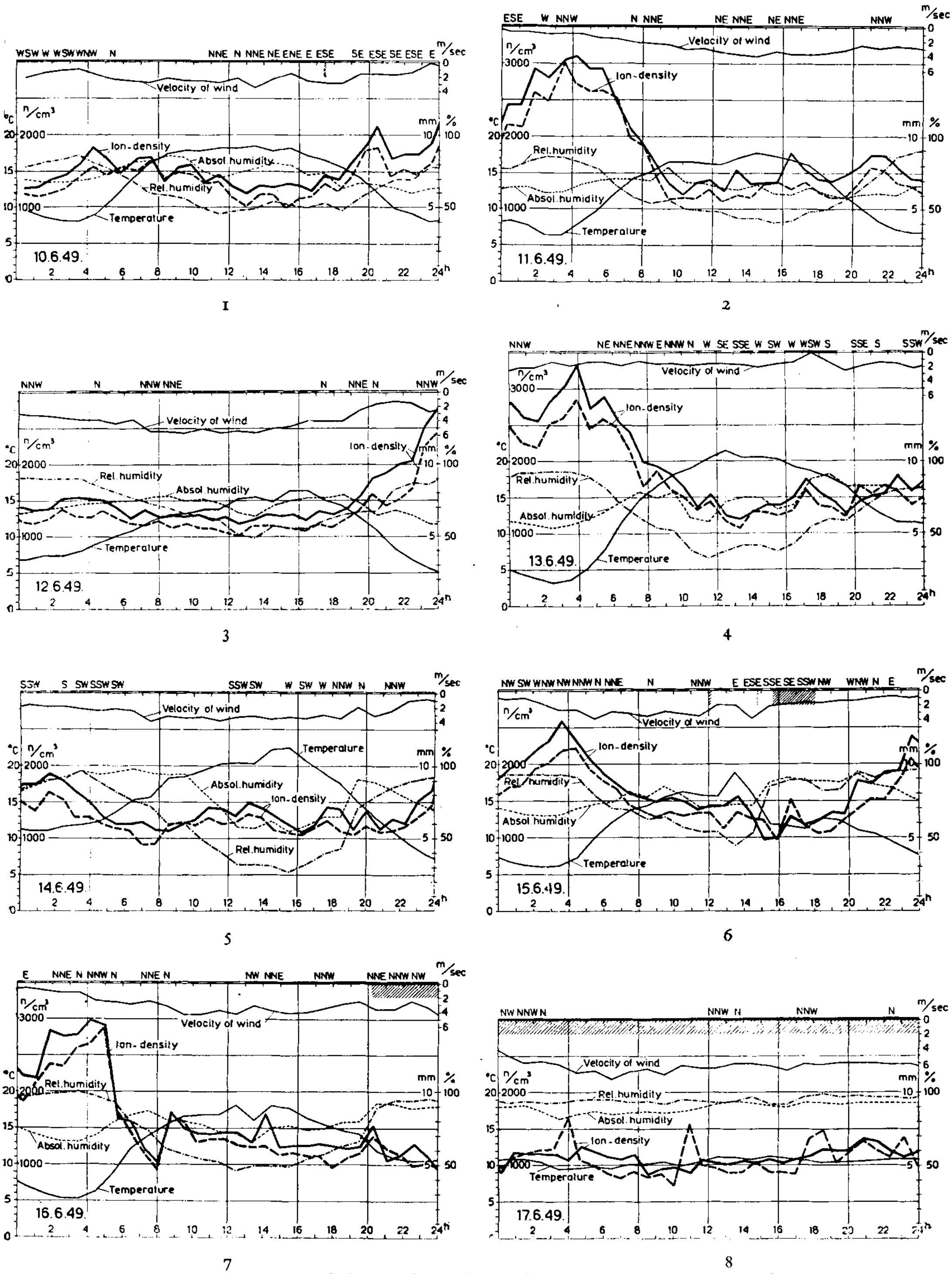

Fig. 1—8: Variation of the small-ion density besides some meteorological factors.

that the mechanism of this accumulation may be the one given by MESSERSCHMIDT (4). For these reasons we may assume that the observed increase of ion-density is caused by an accumulation of the emanation exhaled from the soil.

Concerning the humidity we may state in general that in summer during undisturbed weather, the absolute humidity follows a trend similar to the temperature, and that the relative humidity follows an inverse trend. MESSERSCHMIDT has shown that for different seasons of the year there is no relation between the relative humidity and the emanation content, but that, on the other hand, the absolute humidity and the emanation content run parallel courses. MESSERSCHMIDT's opinion is that the relation between the emanation content and the absolute humidity is fortuitious, and results simply from the fact that the absolute humidity varies in the same sense as the temperature. We shall accept this opinion, since when the increase of ion-density is caused by the accumulation of exhaled emanation, the transformation of newly formed ions into heavier ones cannot take place very rapidly, and the absolute humidity cannot therefore play an important rôle.

It cannot be claimed that the phenomenon here considered must appear everywhere, whenever the meteorological conditions are appropriate. In our case special circumstances can be pointed out which may favour the occurrence of the phenomenon. The investigation of radioactive substances in the air carried out at the Institute (SIKSNA 9, 10) has shown that especially in the cellar-rooms of the Institute building are high contents of emanation and its decay products found. The source of these radioactive substances must be searched for in the soil surrounding the Institute; thus it may be assumed that the action of these sources may be of considerable importance also in the open air.

REFERENCES

(1) EBERT, H., 1909: Registrierung der dem Erdboden entquellenden Emanationsmengen. *Phys. ZS.*, **10**, p. 346—350.

(2) JOLY, J., and SMYTH, L. B., 1911: On the amount of radium emanation in the soil and its escape into the atmosphere. *Proc. Royal Dubl. Society*, **13**, p. 148—161.

(3) KOSMATH, W., 1933: Die Exhalation der Radiumemanation aus dem Erdboden und ihre Abhängigkeit von den meteorologischen Faktoren. *Gerlands Beitr. Geophys.*, **40**, p. 226—237.

(4) MESSERSCHMIDT, W., 1933: Eine neue Methode zur Bestimmung des Emanationsgehaltes der Atmosphäre und ihre Anwendung zur Untersuchung der Zusammenhänge mit den meteorologischen Faktoren und des Einflusses des Emanationsgehaltes der Atmosphäre auf die Messungen der Ultrastrahlung. *ZS. f. Phys.*, **81**, p. 84—100.

(5) NORINDER, H., and SIKSNA, R., 1949: The measurements of the variation characteristics of the density of small-ions. *Arkiv för geofysik*, **1**, 1, p. 1—32.

(6) NORINDER, H., and SIKSNA, R., 1950: Continued measurements of the variation characteristics of the density of small-ions. *Arkiv för geofysik*, **1**, 7.

(7) SCHMID, E., 1931: Der Gehalt der Freiluft an Radiumemanation und deren Verteilung in der Nähe des Erdbodens. *Wien. Ber.*, **140** (2 a), p. 27—48.

(8) SCHMID, E., 1932: Messungen des Radium-Emanationsgehaltes von Kellerluft. *ZS. f. Geophys.* **8**, p. 233—242.

(9) SIKSNA, R., 1950: Photographic emulsion method applied to the investigation of the radioactive deposit from atmospheric air. *Tellus*, **2**. p. 89—92.

(10) SIKSNA, R., 1950: Radioactivity induced from the atmospheric air, investigated with the photographic emulsion method. *Arkiv för geofysik*, **1**, 8.

(11) SMYTH, L. B., 1912: On the supply of radium emanation from the soil to the atmosphere, *Phil. Mag.* **24**, p. 632—637.

(12) WRIGHT, J. R. and SMITH, O. F., 1914: Eine Bestimmung der Änderung des Gehaltes der Atmosphäre an Radiumemanation mit der Höhe. *Phys. ZS.* **15**, p. 31—39.

13) WRIGHT, J. R., and SMITH, O. F., 1915: The variation with meteorological conditions of the amount of radium emanation in the atmosphere, in the soil gas and in the air exhaled from the surface of the ground, at Manila. *Phys. Rev.* **5**, p. 459—482.

(14) ZUPANCIC, P. R., 1934: Messungen der Exhalation von Radiumemanation aus dem Erdboden. *Terr. Magn.* **39**, p. 33—46.