The vertical gradient of Electro-Atmospheric potential at Macerata (Italy)

(Central East Apennines)

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Riassunto. — Nel presente lavoro vengono studiati 11 anni di misure di gradiente verticale di potenziale elettro atmosferico, eseguite nell'Osservatorio Meteorologico di Macerata (Appennini Centro Orientali). Sono stati pertanto calcolati i valori annui medi, mensili medi, e medi orari. I calcoli sono basati su cinque giorni calmi elettricamente, scelti con metodi probabilistici fra tutti quelli calmi del mese.

Della curva media oraria è stata anche ricavata, per mezzo dell'analisi armonica, la equazione; si sono quindi esaminate le armoniche arrestandosi alla terza e trovando che esse rispecchiano le diverse componenti generali e locali come quella dovuta alle masse d'aria continentale e marittima, operanti alternativamente nella regione di osservazione. Il minimo generale delle ore 5 locali (4 di TU) è messo in buona evidenza dalla prima armonica; esso, pur essendo presente nella curva media oraria, appare in questa meno accentuato di quanto si potrebbe pensare dovesse essere.

Sono stati studiati infine gli andamenti del gradiente verticale nei giorni sereni, coperti, calmi e si sono fra loro confrontati i diversi risultati. Si è anche proceduto a studiare l'andamento del parametro elettrico della atmosfera in relazione ai fenomeni solari, in particolare con l'andamento delle macchie durante gli 11 anni di osservazioni.

Summary. — This work studies eleven years of measures of the gradient of electro-atmospheric potential carried out in the Observatory of Macerata (East Central Apennines). The medium yearly and monthly values as well as the medium hourly values have been calculated. The calculations are based on the values of five calm days chosen with probabilistic methods from all the calm days of the month considered.

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The equation has also been found from the medium hourly curve by means of harmonic analysis. Then the harmonics have been examined stopping at the third, and it has been found that these reflected the different general and local components such as that due to the masses of air of maritime origin and that due to the masses of continental air operating alternatively in the region of observation. The general minimum of the local hours 5 a. m. (4 TU) is clearly shown by the first harmonic, and it is also present in the medium hourly curve but appears in this less accentuated than what we would expect it to be.

Finally the behaviours of the vertical gradient in clear, cloudy and calm days have been studied and the different results compared.

The behaviour of the parameter of the atmospheric electricity in relation to the solar phenomena has also been studied and in particular with the behaviour of the sunspots during the eleven years of observations.

1) The present work studies the characteristics of the vertical gradient of electro-atmospheric potential at Macerata (Central East Apennines) at latitudes of 43°17′45″N, longitude 13°27′08″E.Gr., altitude 338 metres over a period of eleven years and follows on another work ([21]) that showed and commented on the measures carried out in the first six years of research.

The station is built on a large terrace almost completely free of obstacles at the top of a hill situated astride two wide river vallies.

The location has certainly influenced the research accentuating the values measured of the gradient, as we can see from these same measures and when these are compared with other measures carried out in stations differently situated. The instrument employed, still in use and in perfect working order, is a valve electrometer constructed in the Geophysics Institute of the University of Genoa ([2]). A tape-recorder was fitted and this has improved its services. The registration speed is 5 cm/ph but this can be reduced or increased to show the behaviour of the measure more clearly.

2) As we know, the vertical gradient of electro-atmospheric potential in proximity to the ground can be expressed with $V = \dfrac{E}{R\lambda}$ where E indicates the difference of potential between the two plates of the ideal condenser formed by the terrestrial surface and the layer of the ionosphere situated at about 60/70 km ([4,8]): λ is the conductivity of the air in proximity to the terrestrial surface, while R is the columns resistance.

Table I – Medium yearly values of the vertical gradient of electro-atmospheric potential.

Calm days

	1958	1959	1960	1961	1961	1963	1964	1965	1966	1967	1968	Media
January . .	104	137	130	136	92	168	137	116	199	159	112	135
February . .	134	113	145	181	126	124	131	165	183	231	85	147
March . . .	45	155	177	189	104	204	135	152	192	147	81	144
April	148	178	165	171	192	238	147	100	180	139	176	167
May	147	151	182	195	234	237	161	107	179	144	178	174
June	149	184	215	251	211	212	276	157	224	125	202	200
July	215	209	200	188	237	209	262	142	191	118	174	195
August . . .	147	163	220	260	208	211	198	160	196	159	167	190
September .	197	113	151	232	195	213	153	166	212	156	159	178
October . .	164	182	160	170	163	151	156	175	133	162	122	158
November .	130	151	148	187	125	112	177	155	103	152	148	144
December . .	150	162	140	160	97	80	112	152	177	86	85	136
Medium . .	142	156	168	193	165	180	170	166	181	148	139	165

Therefore the gradient of electro-atmospheric potential clearly appears to depend on the general conditions and particulars existing in the atmospheric layers that modify the column resistance and the conductivity, such as cosmic radiation, storm activity, solar activity, solar radiation, the humidity of the lower layer, fog formation, etc.

3) Table I gives the medium yearly and monthly values of the gradient of potential for the years 1958-1968 and the respective aver-

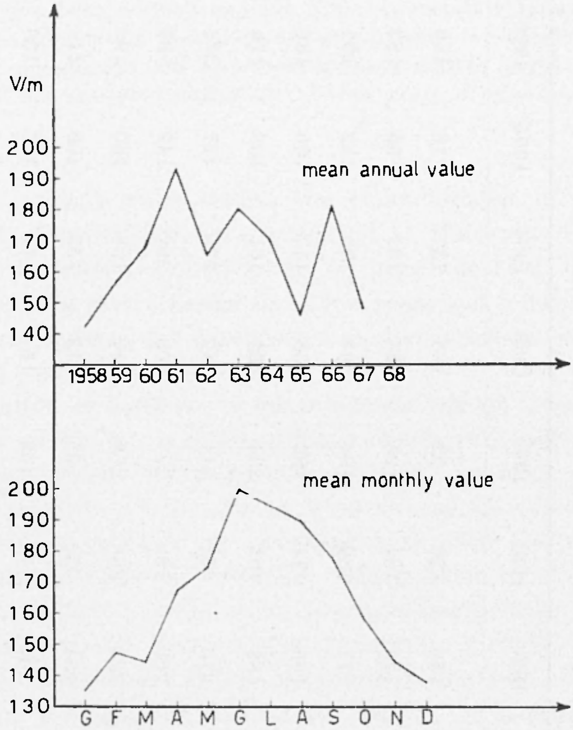

Fig. 1 – Medium yearly values and medium monthly values of the vertical gradient of electro-atmospheric potential at Macerata.

ages. The medium values indicated have been found by choosing with stochastic procedure five days from the electrically calm days of the month considered. The general behaviour is indicated in the graphs of Fig. 1.

On the same values of the electrically calm days the medium hourly values of the gradient have been calculated: these are indicated in Table II and graphed in Fig. 2.

Table II – MEDIUM VALUES OF THE VERTICAL GRADIENT OF ELECTRO-ATMOSPHERIC POTENTIAL.

Calm days – 1958-1968

Hour	Vertical gradient V/m	Hour	Vertical gradient V/m
1	161	13	181
2	159	14	179
3	152	15	175
4	152	16	163
5	154	17	169
6	153	18	162
7	155	19	162
8	163	20	167
9	167	21	168
10	175	22	167
11	178	23	166
12	182	24	165

Medium 165 V/m.

The medium yearly value found from the measures of the eleven years is 165 volts/m. in excellent agreement with the values found by other researchers, taking into account the position of the station on the

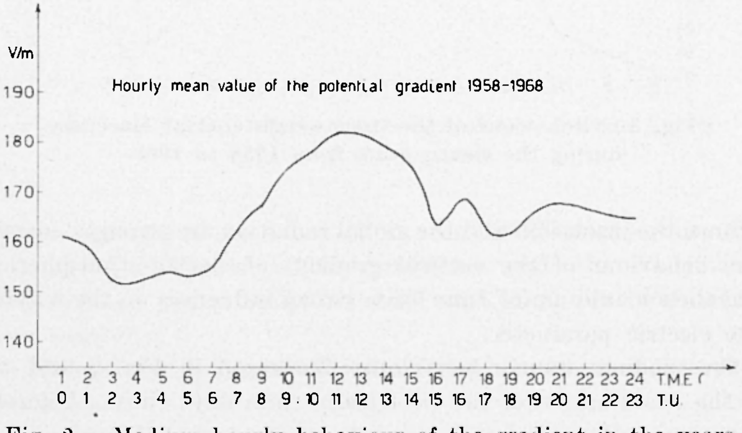

Fig. 2 – Medium hourly behaviour of the gradient in the years from 1958 to 1968.

top of a hill (6). The examination of the monthly behaviour shows the relative maximum of February, the relative minimum of March, the absolute maximum of June. As regards the values calculated previously ([22]) such maxima and minima appear much more accentuated; in particular the maximum and the minimum relative to Winter appear clearly defined, in relation to the meteorological situation that are present in the region of observation. Situations often anticyclonic in February with clear weather, low relative humidity, high temperatures, strong solar radiation; depressions in March with continuous rain, strong relative humidity, increasing storm activity, low solar radiation.

The maximum of June coincides with the maximum of the clear days and with that of the electrically calm days, even if in the same period the maximum of storms recorded in the stations fell (Fig. 3).

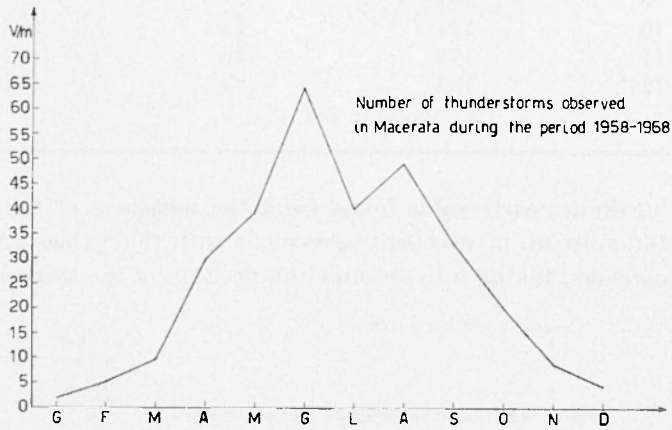

Fig. 3 – Behaviour of the storms registered at Macerata during the eleven years from 1958 to 1968.

Since the insolation and the global radiation are strongly correlated to the behaviour of the vertical gradient of electro-atmospheric potential their maximum of June has a strong influences on the maximum of the electric parameter.

The medium hourly behaviour, illustrated in Fig. 2 and taken from the examination of the electrically calm days chosen beforehand for every month considered, presents an accentuated minimum between the hours 3 and 6 a.m. TMEC (2 and 5 TU), in agreement with the general behaviour found for any other station of the hemisphere, and in agreement with the recent views expressed on the absorption of solar radiation by the oceans and by emersed lands ([3]).

The solar radiation absorbed by the Earth presents a daily universal behaviour in relation to the different albedo of the seas and the emersed lands, to the different absorptions, etc. The daily universal behaviour of this element presents a minimum towards the hour 4 a.m. (TU). The Earth's electric field presents a behaviour parallel to the former; the time of the minimum of the vertical gradient obtained by us is in good agreement with the minimum of the behaviours predicted.

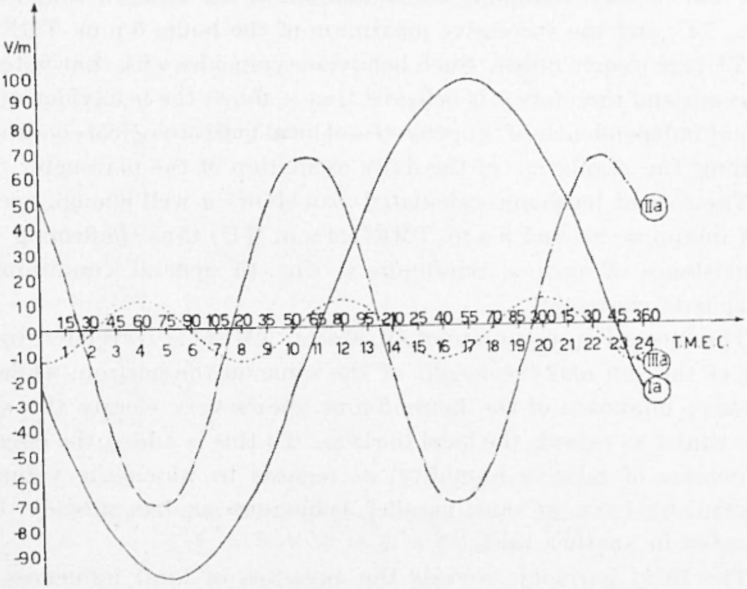

Fig. 4 – Behaviour of the harmonics of the medium hourly curve of the gradient.

The maximum of the hours 12.30 p.m. TMEC in proximity to the local noontime is presented in concidence with the maximum of direct solar and global radiation and with the local minimum of relative humidity.

It appears clearly characterized in the whole series of observations carried out.

4) The medium hourly values of the vertical gradient have been examined by the methods of harmonic analysis.

An equation representative of the curve has been obtained and the harmonics of this have been calculated. These are shows in Fig. 4.

The equation is:

$$V\,(V/m) = 165{,}6 + 98{,}3 \text{ sen } (x + 192^\circ) + 70{,}3 \text{ sen } (2x + 130^\circ) + + 12{,}5 \text{ sen } (3x + 265^\circ) + 0{,}218 \text{ sen } (4x + 71^\circ)\,.$$

The equation has been stopped at the 4th term and therefore the first three harmonics have been calculated. It was thought useless to calculate the fourth it being held of little account.

From the first harmonic the minimum of the hours 5 a.m. TMEC (4 a.m. TU) and the successive maximum of the hours 5 p.m. TMEC (4 p.m. TU) are clearly noted. Such behaviour coincides with that noted on the oceans and therefore it is believed that it shows the behaviour of the gradient independently of the general and local meteorological conditions, revealing the regularity of the daily oscillation of the parameter [18, 4].

The second harmonic calculated also shows a well enough accent uated minimum around 5 a.m. TMEC (4 a.m. TU) thus confirming that the existence of such a minimum is due to general conditions of hemispheric character.

The successive maximum of 10.30 a.m. TMEC is correlated to the rising of the sun and the height of the same on the horizon, while the successive minimum of the hours 5 p.m. shows very clearly the effect of the sunset as regards the local horizon. To this is added the effect of the increase of relative humidity, as regards to which the values of the gradient have an anti-parallel behaviour as has already been illustrated in another work [22].

The third harmonic reveals the presence of local influences and situations and above all of the superimposition of the two continental and maritime components allied to the different dynamic situations to which the observation site is subject during the course of the meteorological year.

In the rather long period of observation the situations dominated by the afflux of continental air from the NE and E, and those dominated by the arrival of Mediterranean sea air or Atlantic air are divided in almost equal manner with a slight advantage of the former (55% as against 45%).

Therefore the two behaviours, continental and maritime, the first with two maxima and two minima, the second with a maximum and a minimum, superimposed with the purely local oscillations, are well enough represented on the whole by the 3rd harmonic, which shows the regular variations of the gradient following on the regular alternating during the day of the local winds (mountain and sea breezes) that reach and affect in full the observation station situated at an equal distance (25 km) from the sea and from the Apennine chain.

5) The examination of the values of the vertical gradient of the electro-atmospheric field has been extended also to single seasons, considering calm, clear and cloudy days. Table III gives the medium values calculated for every single season of calm days, while Figs. 5, 6, 7 give the behaviour in the three cases indicated above.

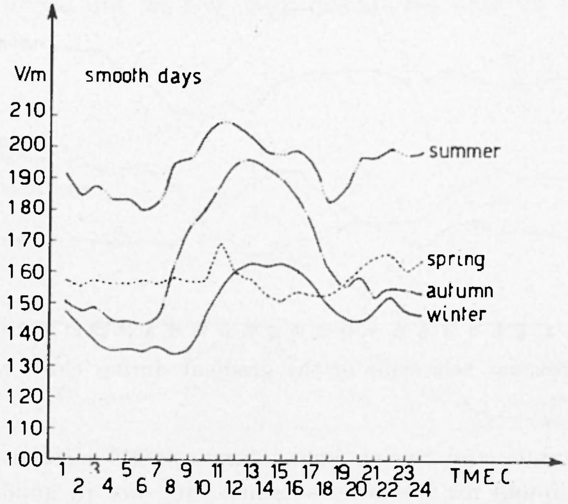

Fig. 5 – Medium seasonal values of the vertical gradient of potential during calm days.

The behaviour during calm days presents the principal maximum in Summer, the minimum in Winter, reaching intermediate values between these in the two other seasons. The difference between the maximum of Summer and Winter values is 35 V/m, while between those of Spring and Autumn the difference is 27 V/m.

The hours in which the maxima are reached are between 12 and 1 p.m. (TMEC) in Winter and Autumn, between 11 and 12 a.m. (TMEC) in Spring and Summer. The maximum in Winter is not perfectly definite since during that season there are presented two equal values between the hours 12/1 p.m. and the hours 2/3 p.m. We believe that this occurrence is due to eminently local causes such as the breeze from the valley that during the Winter rises locally reaching a peak between 1 and 2 hours p.m., determining a strong *austausch* effect and a consequent greater ionic activity with consequent diminuition of the gradient.

The average daily behaviour of the vertical gradient during the calm days is illustrated in Fig. 6. It presents in Autumn and Winter an absolute maximum between the hours 12 and 1 p.m. TMEC in Autumn, between the hours 2 and 3 p.m. in Winter.

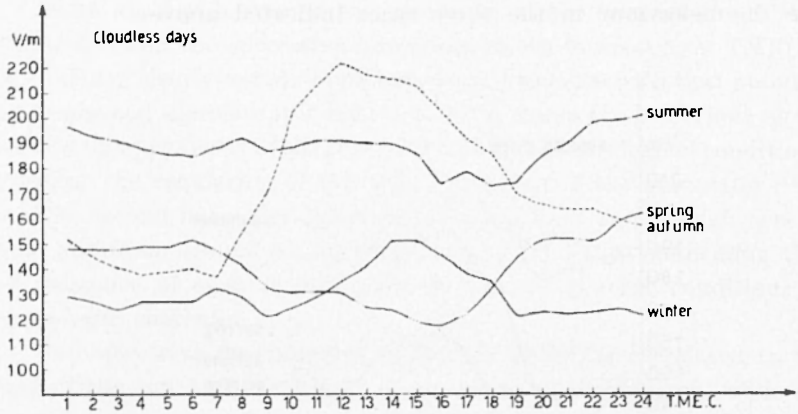

Fig. 6 – Seasonal behaviour of the gradient during clear, calm days.

The Summer and Spring behaviours appear parallel and clearly unlike those found for the other seasons: they are in good agreement with those found by other researchers ([28],[2]).

The Summer behaviour without clear maxima and minima appears so because of the ever present and active remingling of the mass of air that is found in the observation station (placed on top of a hill) particularly on clear days and due to the strong vertical currents. The active remingling produces a sensible incision in the recorded diagram due to the ionic activity with variations around the instantaneous value of $\pm$ 5 *V/m*. Such variations disappear in occasion of rains and in the night hours during the pause between the inversion of the mountains and valley breezes, as has been noted elsewhere ([6]).

The same considerations can be made for the Spring, season for which it is however necessary to note that on clear days there is a clear minimum towards the hours 4 p.m., during which the vertical gradient presents a variation of — 45 *V/m* as regards the medium annual value and of — 39 V/m as regards the medium seasonal value. This minimum so strongly accentuated appears correlated to the irradiation fogs that form in the region of observation at sunset ([8]).

The coefficient of correlation between the presence of these fogs and the diminution of the gradient has been calculated by us to account for the Spring minimum that does not appears in other stations in which the measures have been studied. Its value resulted:

$$r = 0{,}89$$

and therefore very significant, bearing in mind that the calculations have been carried out on 380 cases distributed over 10 years of observations.

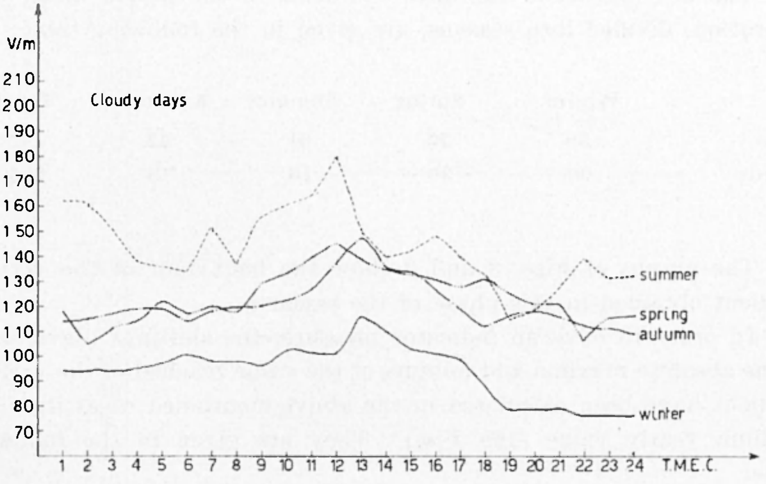

Fig. 7 - Seasonal behaviour of the gradient during calm, cloudy days.

The effect of the sunrise (Muhlheisen) ([8]), is particularly sensible during Autumn and Winter, as we can see from Fig. 6, while it is much less decided in Spring and Summer.

The behaviour of the vertical gradient has also been calculated for completely cloudy calm days.

This is indicate in Fig. 7.

As we can see, in these days the absolute maximum values occur in Summer and Spring towards the hours 12 a.m. TMEC in coincidence with the maximum of global solar radiation, while in the other seasons they occur towards hours 1 p.m., always in coincidence with the maximum of global solar radiation. The secondary maxima and minima that we see are correlated to the type of clouds that appear on the vertical of the observation station. In particular the different Summer maxima and minima are allied to the pullulant cloudiness that forms on the nearby Apennine chain because of the convective motions rendered very violent by the relative nearness of the sea to the same (50/70 km distance and even less) and by the strong incision of the oreography that determines great thermic differences on neighbouring areas.

6) It was held useful to enquire deeper into the behaviour of the vertical gradient in the observation station to examine the relation between the seasonal behaviour in calm days, totally clear and totally cloudy days.

The distribution of the days examined in the period under consideration, divided into seasons, are given in the following table:

	Winter	Spring	Summer	Autumn	Total
Clear	30	23	61	32	145
Cloudy	90	30	16	70	206

The graphs of Figs. 8 and 9 show the behaviour of the vertical gradient obtained in this phase of the research.

In order to have an indicator measure, the shiftings (deviations) of the absolute maxima and minima of the value reached of the vertical gradient have been calculated in the above-mentioned cases from the medium yearly value (165 V/m). They are given in the following table:

		Winter		Spring		Summer		Autumn	
Shiftings of the Maxima and Minima from the Medium value		Max	Min	Max	Min	Max	Min	Max	Min
Clear	V/m	— 43	— 12	0	— 45	+ 38	+ 10	+ 59	— 26
	%	26	7	0	27	23	6	36	16
Cloudy	V/m	— 47	— 87	— 18	— 57	+ 17	— 48	— 24	— 54
	%	28	53	11	35	10	29	15	33

The values found appear in agreement with those found by other authors. The presence of cloud cover has the effect of lowering the value of the vertical gradient of electro-atmospheric potential, as on the other hand, all the different yearly and seasonal relations calculated by us clearly show, considering the values of the vertical gradient measured in the totally cloudy days (Figs. 7, 8, 9).

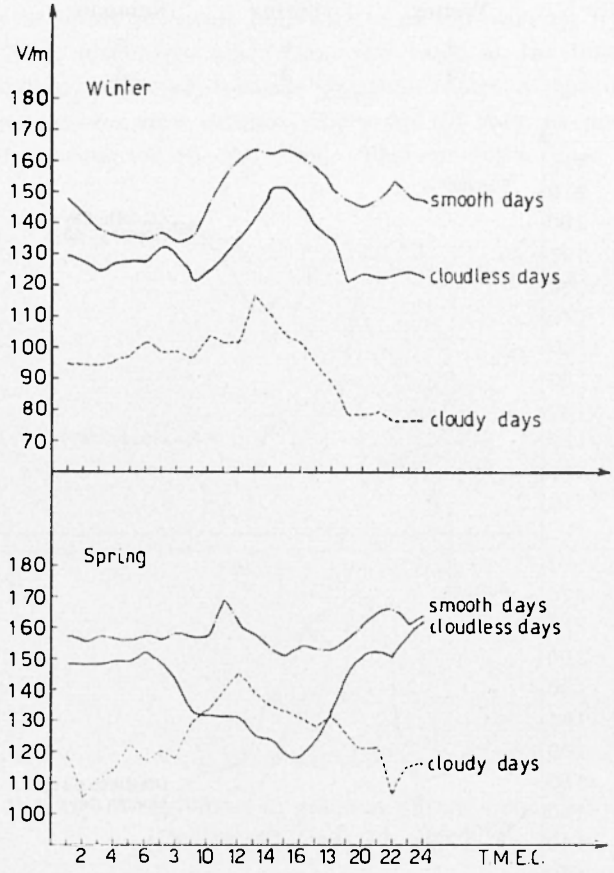

Fig. 8 – Behaviour of the gradient during Winter and Spring on calm, clear, and cloudy days.

7) The vertical gradient of electro-atmospheric potential suffers considerably the effect of the sunrise and sunset. This effect is particularly felt in the calm clear and completely cloudy days. The repeated observations of the phenomenon, extended to all the cases of completely clear or cloudy days of the preceding table have allowed us to calculate the values of the medium variations of the gradient that have then been summarized. The maximum values of dV/dt are verified

in clear Autumn days about 30 minutes after sunrise. The absolute maximum value measured has been 15 V/m to the minute.

Medium values of dV/dt in V/m to the minute at sunrise:

	Winter	Spring	Summer	Autumn
Clear	4	6	5	9
Cloudy	3	4	3	6

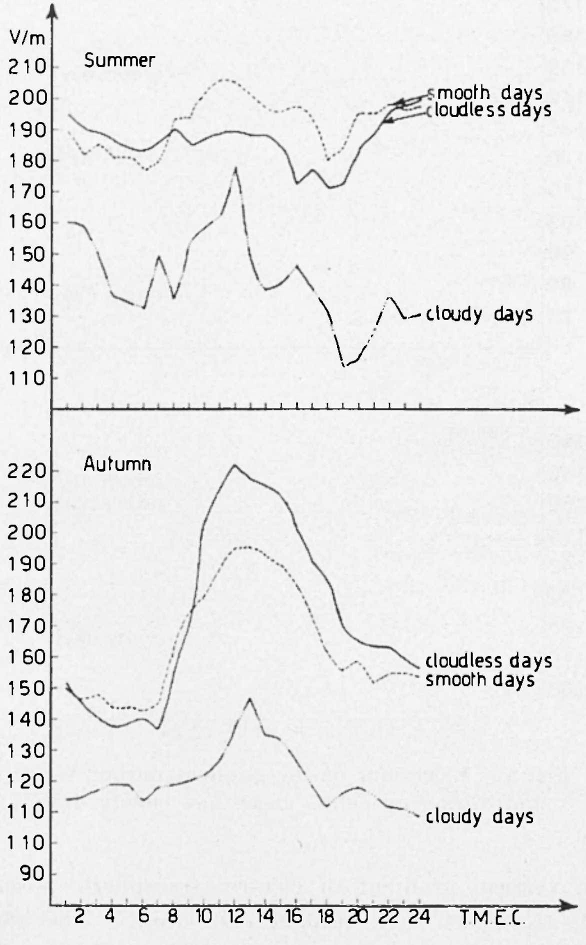

Fig. 9 – Calm, clear and cloudy days.

The medium effect of the sunrise on the values of the vertical gradient of electro-atmospheric potential is therefore around 5 V/m

to the minute in the observation station. The entity of the variation of the gradient at sunset is about half of that measured at sunrise. As was already observed by us during snowfalls there are determined characteristic oscillations of the field with discharges following on each other at short intervals and with a period varying from 2 to 8 seconds. Such discharges start from the value at the instant of the gradient and are directed towards positive values of the same field. Often these assume very intense values up till they go out of scale, and therefore superior to 300 V/m. The cut-down sizes of (small-

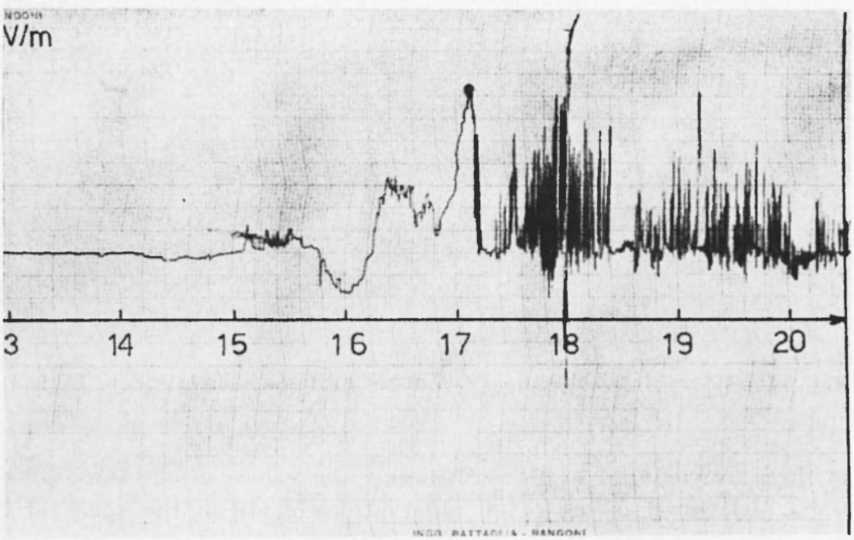

Fig. 10 – Polarity of the potential gradient during a snowfall at Macerata Observatory (Jan. 20, 1968).

scale) diagrams reproduced are relative to snowfalls of the Winter of 1968 (Figs. 10 and 11). The behaviour of the electric field mentioned above is in agreement with that observed in Japan and Canada ([10,14,8]). The snow that fell during the reported observations was dry and crystalline while the temperature remained below — 6°C.

While snowfalls determine a succession of oscillations of very short period, rainfalls determine only an immediate decrease of the value of the vertical gradient. The velocity of diminuition of the gradient is linearly dependent on the intensity of the rainfall. We have found a relation between the electric conductivity of the rain and the values of the vertical gradient of the form:

$$V = \frac{a}{C_0 - K} + b\,,$$

where a, b, k are parameters that depend in part on te season, on the prevailing wind at the moment of the fall of the liquid precipitation, while V is the vertical gradient of potential, and C_0 the conductivity

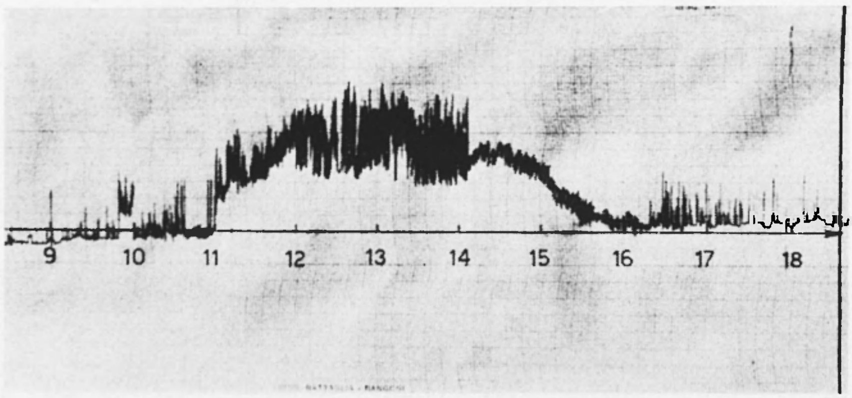

Fig. 11 – The potential gradient behaviour during a snowfall (Feb. 7, 1968).

of the water reduced to 0°C. Mediately the values of the three constants, calculated on over 100 observations made in the space of a year have given for Macerata the value:

$$a = 2548{,}8 \qquad b = -17 \qquad K = +1{,}6\,.$$

A greater number of observations would allows us to better define the relation found, in relation to the different meteorological situations, the seasons, and to the winds.

The behaviour of the vertical gradient, in relation to the clouds present on the vertical of the Observatory is different according to whether the same clouds are cumuli of fine weather present temporarily in clear days, or cumuli of bad weather belonging to a system of depression affecting the whole region of the observation station.

In the first case there are for the greater part discharges directed in the negative field, and for a small percentage in the positive one. Precisely in 311 cases observed of discharges produced in clear days by cumuli of fine weather, 288 cases, equal to 93% of the total, have given discharged directed towards the negative field, 22 cases, equal to 7% of the cases observed, have given discharges directed towards the positive field.

The medium value of the variation of the value of the vertical gradient of electro-atmospheric potential in such events has been calculated in 125 V/m towards the negative field and 45 V/m towards the positive field.

The cases definitely observed of cumuli of bad weather on the vertical of the station that have produced isolated discharges have been 109; almost all the discharges have been directed towards the negative field with a medium variation of the value of the vertical gradient of about 140 V/m. There were also recorded discharges towards the positive field, but of weak intensity and for that reason the are not clear on the diagram, and so we have not taken them into consideration.

The particular winds of the region, such as the *fohn* that generates in the central east Apennines and reaches very high values in the Observatory, also influence the value and behaviour of the vertical gradient. On such occasions the gradient undergoes some very considerable variations with very sensible increases.

8) Having at our disposal more than 11 years of uninterrupter observations of the vertical gradient, we have tried to find eventual correlations between the behaviour of the afore-mentioned electric parameter and that of the solar phenomena in the same period. We have chosen as indicatives of these latter the solar index R_z for the period indicated. Fig. 12 indicates the general behaviour of the two phenomena and the medium behaviour as calculated by us. As we can easily see, the two events present a notable anti-parallelism corresponding to the solar maximum a minimum of the vertical gradient and viceversa.

Such behaviour would be in perfect agreement with the hypotheses of C.T.R. Wilson(1921) and more recently of Kasemir (1962) and Schmerling (1966). The classic hypothesis of the global concept of atmospheric electricity postulates that the Earth and the ionosphere are strong conductor plates of a condenser separated by a dielectric, the atmosphere, imperfect isolator and therefore subject to loss. The discovery of the function of global storm activity, understood to restore energy to the earth-ionosphere circuit can in substance be at-

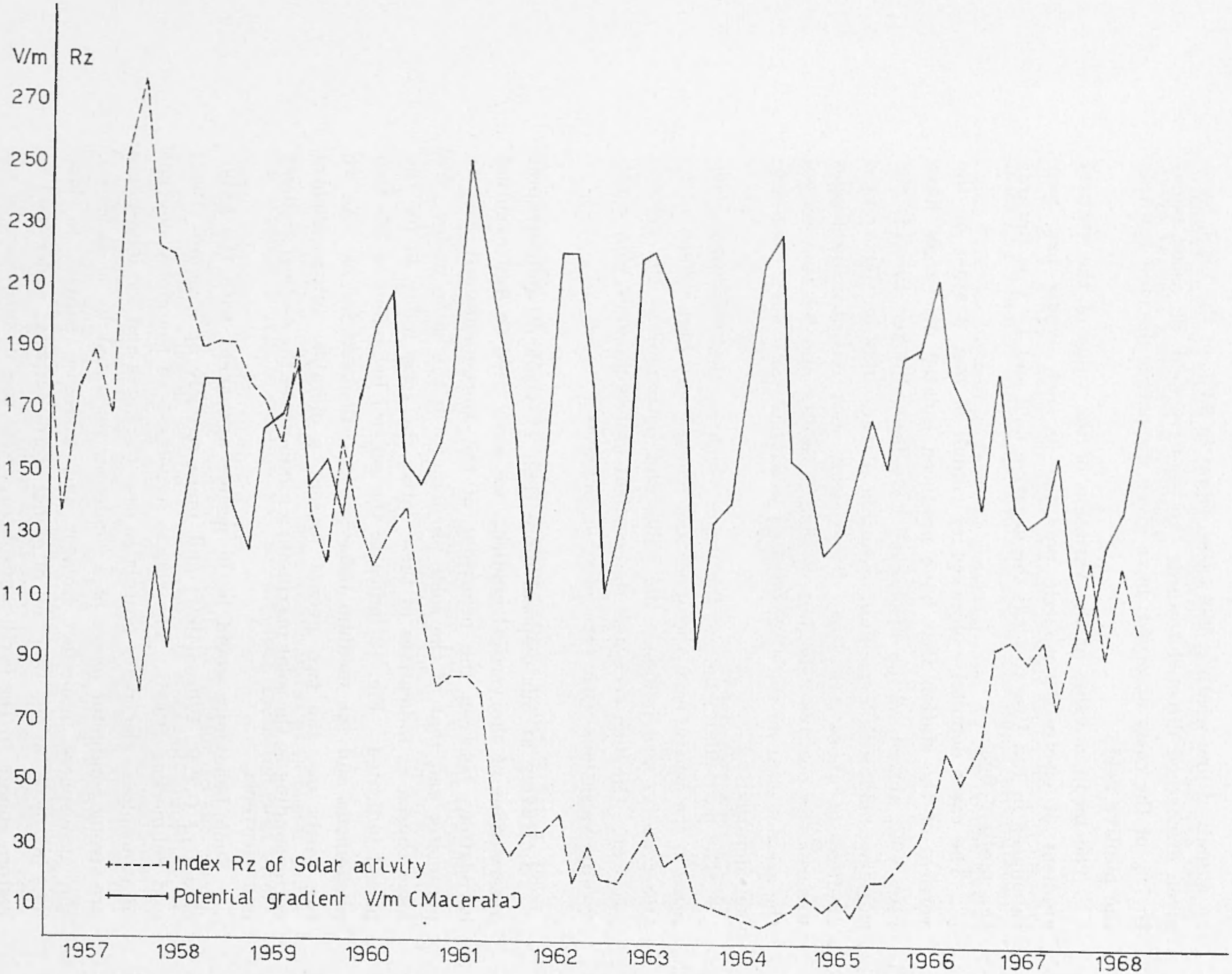

Fig. 12 – General and medium behaviour of Solar Index R_z and of the gradient of potential (Macerata) during the eleven years from 1958 to 1968.

tributed to C.T.R. Wilson. This action often noted as " The Wilson Circuit " can be expressed more briefly like this: above areas of fine weather there existes a flux of positive discharges towards the Earth that tends to lower the potential of the ionosphere and neutralize the negative discharges of the Earth. Above the stormy areas an inverse phenomenon takes place with an intensivity such as to restore the energetic balance.

With regards to the earth-ionosphere condenser, the question that arises is how to determine what effective barrier the higher plate opposes to the penetration of particles charged by part of the out-side space. Now, the upper layer of the atmosphere between 50 and 80 km forms that part called ionosphere, and the part above 50 km is generally considered sufficiently ionized to be able to be considered a conductor.

Schmerling has defined this layer on the whole as the " C layer ". Any spatial charge carried by corpuscular radiation is absorbed by this layer in a quite short lapse of time, precisely in relation to its conductivity.

It is generally thought, however, that this layer cannot be considered as a real electrostatic screen but rather as a variable layer, often not equipotential. Kasemir has calculated that the flow of electric current above the storms can penetrate into the ionosphere and stretch far out into space. The corpuscular solar radiation, on the other hand, would behave inversely penetrating into the ionospere in the opposite direction and therefore reaching, according to the energy, the vicinity of the lower layers and influencing the electric parameters measured there.

In the eleven years of continuous measures of the vertical gradient of potential, we have tried to show the eventual correlations between this parameter and the general activity of the sun. The behaviour is that illustrated in Fig. 12 already mentioned. The indices of correlation for the different years, calculated assuming R_z index (medium bimestrial value) and the corresponding medium value of the gradient as variable statistics, taken in absolute value are:

1958: 0,42	1959: 0,48	1960: 0,48	1961: 0,29	1962: 0,01
1963: 0,88	1964: 0,83	1965: 0,46	1966: 0,10	1967: 0,19
1968: 0,82				

The general index calculated for all the 11 years of observation results 0,40.

It might well be thought that the indices found are expressive enough, considering the circumstances in which the observations were made, especially all those of the gradient of potential whose measures were made in the lower troposphere and therefore suffer all the negative conditions that are connected with such a position ([26]).

The annual variability of the indices arises in our judgement from different causes, the chief of which could be the following:

1) the medium values on which the statistic calculations were made are not perfectly homogeneous. The solar observations from which the R_z index come are not perfectly homogeneous with regards to the measures of the gradient; though they were made in same two-months period, they were not made on the same days. In fact, electrically calm days do not always coincide with days in which the sun is seen.

2) the solar activity presents a very irregular behaviour that influences the values introduced in the calculations.

3) the measures of the vertical gradient of potential are widely influenced by the local meteorological conditions, even if the values introduced in the statistical calculations have been chosen from those belonging to particular days (smooths).

4) the measures of the gradient were influenced, in the period in which it was present, by the fall of " fall-out " resulting from the nuclear explosions in the Sahara and from the Chinese explosions that have affected the latitudinal belt where the observations of the gradient have been made ([11, 12, 13]).

To this latter cause can also be attributed the low values of the index of correlation between the solar activity and the gradient found in the years 1961 and 1962 (French explosions) and in 1966-1967 (Chinese explosions).

The general behaviour once again allows us to say that the maximum solar activity there corresponds a minimum of the vertical gradient and viceversa, which would confirm the already-mentioned hypotheses of C.T.S. Wilson, Kasemir, and Schmerling.

CONCLUSIONS.

Examination of the observations of the vertical gradient of electro-atmospheric potential has shown that this electric parameter is considerably subject to the general meteorological conditions. Its behaviour have been examined in electrically calm clear and cloudy days and in different seasons and the anomalies noted: rain, snow, fog, winds that influence the electric parameter thus lowering its values, or changing its behaviour. Among the values of the gradient and conductivity of the rain there has been found a relation of inverse proportionality that requires investigation by means of a greater number of observations. Sunrise and sunset influence the behaviour of the vertical gradient, increasing or decreasing its value with variations that have been defined and that are greater during the in between seasons coherently with local climatic vicissitudes.

In the search for an eventual correlation between solar activity and the gradient the values of the R_z index and those of the gradient measured by us were compared obtaining a medium behaviour. A minimum of the gradient corresponds to the maximum of solar activity, and viceversa, thus confirming the hypotheses made on the penetration of the solar corpuscular radiation up to the troposphere during the periods of maximum activity.

Finally the indices of correlation between the two phenomena present quite significant values. The general index $R = 0{,}40$, like those of different years that exceed such a value arriving up to 0,88, give, in our opinion, a very effective measure of the intercurrent relations between the two phenomena. The low values of the indices of yearly correlation are found in corrispondence with the lapse of time in which the latitudinal belt of the Observatory was affected by radio-active fall-out coming from the Sahara (French explosions) and from China. The high degree of radioactivity from the air and from the precipitations on those occasions has naturally masked the interdependence of the value of the gradient on the solar activity, introducing a disturbing factor of very high intensity.

Nevertheless the medium behaviour of the two phenomena still appears in a well-defined anti-parallel relation even in those periods, confirming, that there does exist a relation of quite close dependence between the two phenomena.

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