

A case study of weekday variations in electrical parameters at Athens

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Ground-based daily hourly data on atmospheric electrical parameters for the year 1975 at Athens basin, a densely industrialized location, were examined for the identification of the effects of industrial pollutants on electrical parameters during weekdays. The results showed that on Sundays the average values of conductivity and potential gradient were 12% higher and 10% lower, respectively, than the annual mean and on Mondays these values were lower and higher, respectively, by about the same value. The analysis of the data suggested that on Sundays and Mondays alone, the variations noticed in the electric parameters were opposite and extreme in nature, perhaps suggestive of an inherent 7-day periodicity in them. The possibility that this periodicity may also correspond to the solar-sector-boundary-crossing events was also verified.

1 Introduction

The local variations in the atmospheric electrical parameters were earlier considered to be due to noise. However, they are now considered to give information on the meteorological conditions in the lower layers of the atmosphere, particularly, of the particulate content. It was found¹ that daily variations of atmospheric pollution and potential gradient at Kew were very similar, i.e. both showing parallel 12-hr oscillation and explained the double oscillation at Kew as a joint result of production and vertical transport of pollution particles. Muhleisen² showed that diurnal variations of potential gradient near towns are mainly caused by positive space charges produced chiefly by urbanization, industry and traffic. The results of the study undertaken, utilizing the data of potential gradient at Pune for the period 1930-1965, were reported^{3,4}. The results^{3,4} indicated that there is a marked increase in the value of potential gradient, which was attributed to the increase in the dust content and decrease in electrical conductivity. The study of diurnal and seasonal variations of space charge and potential gradient at Pune was made by Selvam *et al.*⁵, which lead to the conclusion that the diurnal course of the two parameters exhibited, by and large, double oscillation which was generally observed in the continental environments.

In some other studies the effects of industrial emissions on potential gradient in the close and near vicinity of a thermal power plant were reported⁶. These observations revealed that the potential gra-

dient was highly negative in the presence of plume released from the industrial chimney stacks. A statistical study⁷ of long-term (1930-1987) variations of potential gradient at Pune was made and it was found that there was a significant increase in the average value of potential gradient at Pune during 1930-1987, which was attributed to the variations in the atmospheric electric conductivity resulting from urban activity.

From the studies reported so far it appears that the aspects of diurnal, seasonal, annual, long-term and incidental variations of surface atmospheric electric parameters were examined more frequently by different workers at different stations, but the aspect of weekday variations of electric parameters has been reported much less except for few cases^{1,8-10}.

Since the governing conditions of the human life style and the growing air pollution are, on an average, linked together and may have influence on the surface electric parameters¹¹, it is felt that parallel with the problem of pollution by domestic, industrial and vehicular activity etc., the normal state of the electric parameters may also be altered. We, therefore, thought it worthwhile to examine the variations in the electrical parameters on weekdays using one year (1975) data at Athens (lat., 37°53'N; long., 23°24'E; 107 m asl).

2 Topography, climate and pollution sources of Athens

mountains on three sides and sea on the fourth side. The basin is bisected by a series of small hills. Most of the industrial activity is located in the south-west (SW), near the harbour of Piraeus having textile, food, cement, chemical, fertilizer, paint and paper factories. Refineries, shipyards, steelworks and the airplanes of Hellinikon airport also contribute significantly to the local pollution even though they are located outside the basin¹². The climate of Athens is Mediterranean with hot dry summers (May-August) and wet mild winters (November-February). The average daily winter temperature is 10.2°C and the daily minimum temperature drops below freezing point only twice a year (absolute minimum temperature is -6.8°C). In summer, the average temperature is 31.0°C. Most of the annual rainfall occurs in the months of October-February.

3 Data and analysis

Daily hourly data of potential gradient (PG), air-earth conduction current (i) and conductivity (λ) were taken from the *Bulletin of Atmospheric Electricity*¹³. One year data were analyzed for monthly, hourly and weekday mean values. The analysis of the data was carried out through a computer system (ND-560) available at the Indian Institute of Tropical Meteorology (IITM), Pune.

The weekday analysis of the above parameters was accomplished in the following way. To start with, 1 Jan. 1975 was confirmed as Wednesday. Since the day on 1 Jan. 1975 could be fixed, it was also possible to fix the dates with days throughout the year. It was thus convenient to pick up the values of the concerned parameter for a given weekday and proceed with the analysis. All the individual hourly values pertaining to all Sundays (for example) occurring during a month were picked up, and a Sunday mean value of that month was obtained and expressed as a percentage of the net monthly mean value. Identical procedure was followed for mean values on other weekdays which were also expressed as percentages of the net monthly mean values. Following the same procedure, the weekday analysis for 12 months of the year 1975 was completed.

4 Results

4.1 Percentage of annual mean on weekdays

Figure 1 shows the average percentages, on weekdays, of monthly mean values of potential gradient, conductivity and air-earth conduction current for 1 yr period. From Fig.1 it may be noted that mean values of potential gradient (PG) and air-earth conduction current (i), from Tuesday onwards till Saturday,

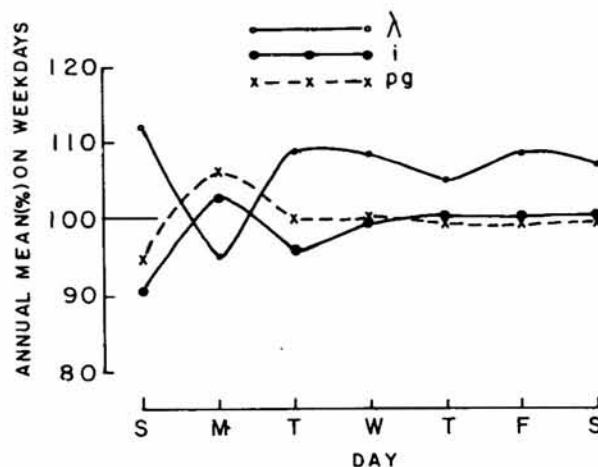


Fig. 1—Average percentages on weekdays of monthly mean values of potential gradient, air-earth conduction current and conductivity for the year 1975 at Athens

lie closer to the annual mean value. The trend for conductivity (λ) is also more or less same as that of the other two parameters.

However, it may be noted that on Sundays and Mondays alone the mean values of the electrical parameters are seen to deviate maximum from the annual mean. The air-earth conduction current and potential gradient on Mondays are higher than the mean by 3 and 6%, respectively, and conductivity is lower by 5%. On Sundays, the potential gradient and current is lower than the mean by 5 and 8%, respectively, and conductivity is higher by about 12%. The inverse variational trend noticed between potential gradient and conductivity on Sundays and Mondays appears to be consistent and noteworthy, since potential gradient is expected to be reduced on higher conductivity values and vice versa. Since the deviations from the mean for electric parameters on Mondays and Sundays alone are maximum and in opposite sense, it was put to 'student's t -test'¹⁴ for obtaining its significance. In case of potential gradient, it was found that Monday vs Sunday deviation was significant at 2.5%, while Monday vs other days deviation was significant at 10% level. Above features, therefore, suggest that the relative difference noticed in the values of the electric parameters on Sundays and Mondays is noteworthy and needs further examination.

4.2 Monthly mean variation

In Fig.2 the monthly mean values of the two electrical parameters are plotted for Mondays and Sundays for the year 1975. Following observations may be noted from Fig.2.

(i) Annual mean value of potential gradient on

Sundays (320 Vm^{-1}) is 8% lower than that on Mondays (350 Vm^{-1}).

(ii) The peak maximum values of potential gradient ($\sim 400 \text{ Vm}^{-1}$) on Mondays are attained in four different months during the year, but such a feature is absent all throughout the year on Sundays; rather the fluctuations in potential gradient on Sundays are nearly non-prevalent.

(iii) Conductivity value on Sundays in 7 different months is seen to be higher than on Mondays by an average 10% which lay in the range 1-25%. It was also noticed from the monthwise comparisons of conductivities that the annual mean conductivity on Sundays was higher than that on Mondays by 5%.

4.3 Annual diurnal variation

In order to reconfirm the differences on Mondays and Sundays noticed previously in the electrical parameters, the hourly data on Sundays and Mondays for potential gradient and conductivity for the year

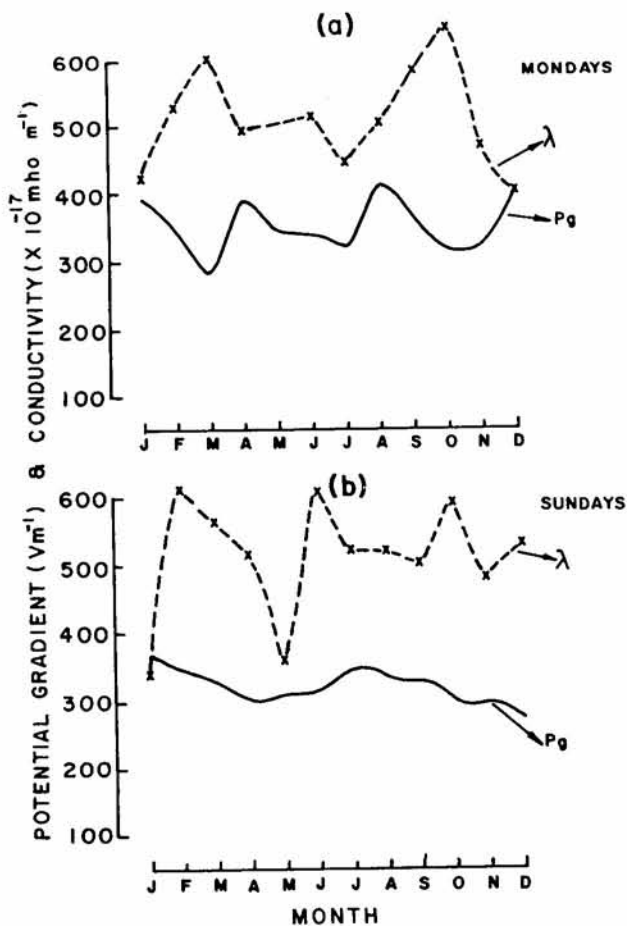


Fig. 2—Monthly mean values of potential gradient and conductivity on (a) Mondays and (b) Sundays for the year 1975 at Athens

1975 were analyzed for annual diurnal variation. Hourwise values on Sundays and Mondays during the year were added and the hourly means were obtained to get the annual diurnal variation curves (Fig.3) for the two weekdays. It may be noted from Fig.3 that mostly throughout the diurnal course, the potential gradient on Mondays was higher than on Sundays. The analysis showed that the peak increase in hourly potential gradient on Mondays relative to Sundays was 35% which occurred around 1400 hrs LT, while the mean diurnal increase on Mondays was higher than on Sundays by $\sim 12\%$. It may be further noted that the diurnal curves on the two weekdays exhibited identical double oscillation with the first and second maximum around 0800 and 2100 hrs LT, respectively, which is a feature reported^{15,16} at Athens and at various land stations^{5,7,17}.

Figure 3 also shows the annual diurnal variation of conductivity on the two weekdays as explained earlier. It may also be noted that all the features which are described in respect of potential gradient on Mondays and Sundays are seen to be reflected also through the conductivity curves in the right sense. The correlation coefficient between potential gradient and conductivity on Sundays was -0.781 , while on Mondays it was -0.716 ; both being significant, the higher value on Sundays is to be noted. Relative decrease in the value of correlation coefficient on Mondays, as a whole, suggests an increase

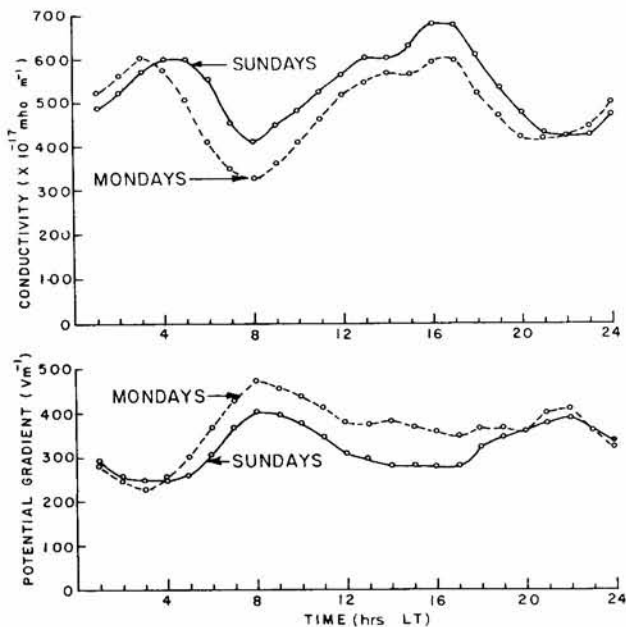


Fig. 3—Annual diurnal variation of potential gradient and conductivity on Mondays and Sundays for the year 1975 at Athens

in the number concentration of large ions and decrease in that of the small ions as an effect of pollution. Earlier^{18,19} and recent studies²⁰ on polar conductivities and contributions of ion species near the earth atmosphere corroborate the present results. Therefore, the higher negative value of correlation coefficient between potential gradient and conductivity on Sundays is of specific significance in relation to the problems of pollution. It may be noted that the difference in conductivity between hourly values on Mondays and Sundays widens during daytime and reduces in the nighttime (1900-0400 hrs LT). This is also true in case of potential gradient. The analysis further indicated that the average conductivity value on Sundays was higher by $\sim 8\%$ than on Mondays. This result appears to be consistent with the lower values of potential gradient on Sundays.

5 Discussion and conclusions

From the analysis of daily hourly data for 1 yr period on atmospheric electrical parameters at Athens, the nature of their variations on weekdays has been studied through annual, monthly and diurnal patterns and the results obtained are validated. The results showed that on Sundays, the weekly off-days for the industries, the average value of conductivity and potential gradient was 12% higher and 10% lower, respectively, than the annual weekdays values, but on Mondays, the initial working days of the weeks, these were lower and higher by about the same value. A scrutiny of earlier works involving similar studies was made. Very few reports⁸⁻¹⁰ came to our notice. Results of our studies do corroborate those findings⁸⁻¹⁰ to a reasonably good extent. Manes¹⁰, in his studies for weekly patterns in conductivity at Bet-Dagan, Israel, in relation to industrial aerosol pollution, noted an increase by 20% on "Sabbatical" (holidays) days over the working days (see Fig. 4). Our results suggest that the change from Sunday average value of potential gradient (320 Vm^{-1}) to Monday value (350 Vm^{-1}) is governed by local variation in conductivity on the two days, which is markedly altered on account of concentration of pollution nuclei into the lower atmosphere through local sources of pollution (various industries, factories, etc.) at Athens. Results analogous to above were reported⁹ for Germany.

The weekday variations of atmospheric electrical parameters as seen from the monthly average data (Fig. 2) appear to be simultaneously affected by the contribution of seasonal variability^{10,15,16}. A good deal of work, relating the surface meteorological and electrical parameters with air pollution at Athens, has been reported by many workers^{12,15,16,21,22}.

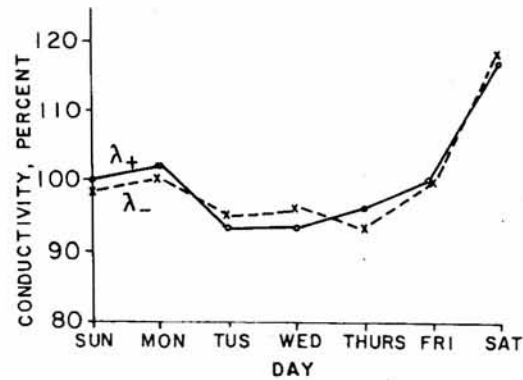


Fig. 4—Weekly variation of positive and negative conductivities at Bet-Dagan (Israel) during 1966-1968 in percentage of the mean

According to their studies the most obvious period of air pollution was identified during Winter (November-February) and the period of minimum pollution in Summer (May-August). Our results for the above two pollution periods suggested (Fig. 2) 6% increase in conductivity and 11% decrease in potential gradient on Sundays over Mondays during peak pollution period, whilst during the other period, conductivity increased just by 2% and potential gradient reduced by 8%.

While the above results reveal the seasonal variation in electrical parameters on working and non-working industrial days (Sundays and Mondays), it also supports the notion of possible weekday variations.

Katsoulis¹² studied some meteorological aspects of air pollution in Athens, Greece, using data for the period 1970-1983. His results showed that the year 1975 was marked with minimum number of air pollution episodes, as defined by him, while the maximum episode years were 1970-73 and 1981. In view of the industrial air pollution at Athens and its basin topography²³, the present analysis of the data for the year 1975 (year of minimum air pollution) was done and weekday variations in atmospheric electrical parameters were identified.

Recent experimental and theoretical investigations relating to the electrical coupling between the troposphere, ionosphere and magnetosphere have suggested the possible solar influence on atmospheric electric parameters and have also indicated that the periodicity of this influence may be roughly 7 days²⁴⁻²⁶. The results of weekday analysis presented in this paper also hinted at the existence of 7-day periodicity in surface electric parameters, since on the two weekdays these parameters showed a typical maxima/minima. In order to confirm the existence of 7-day periodicity, the daily average potential gradient data at Athens, for the year 1975, was sub-

jected to harmonic analysis. The results of harmonic analysis also showed that there existed a 7-day periodicity in surface atmospheric electric parameters at Athens.

Thus, the predominance of 7-day periodicity suggesting solar influence and also the influence of local pollution at Athens on surface atmospheric electric parameters may have something in common and it is quite possible that the two effects may be acting simultaneously. It is realized that the exact cause and effect relation of the 7-day periodicity in surface atmospheric electric parameters at a location such as Athens, vulnerable for pollution effects, needs an examination of long term data sets of surface atmospheric electric parameters and solar-sector-boundary crossing events, before any conclusion can be drawn.

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