Association among Geomagnetic Activity, Atmospheric Electric Field and Selected Meteorological Parameters

Poonam Mehra
Indian Institute of Tropical Meteorology, Pune 411 005, India.
Received July 10, 1989

ABSTRACT

The association among the geomagnetic activity (A_p index) and atmospheric electric field, meteorological parameters was investigated using a long series of continuous data set available for Colaba (18° 53'N, 72° 48'E, 11m ASL) for the period 1936–1966. The meteorological parameters used for the investigation are the surface pressure, temperature, wind velocity and relative humidity. The results of the above study indicate that the atmospheric electric field and the meteorological parameters are associated with the geomagnetic storms with $A_p > 100$. The atmospheric electric field shows an increasing trend after the geomagnetic storm. The surface pressure dips and surface temperatures increase after a geomagnetic storm. The wind velocity shows a decreasing trend and the relative humidity shows an increasing trend after the geomagnetic storm.

I. INTRODUCTION

Sun–weather / climate research is a topic of considerable controversy and potential importance within the realm of solarterrestrial relations (Pittock, 1978; Taylor, 1986). A lot of interest was generated by the pioneering work of Shapiro (1954) and Macdonald and Roberts (1960) who noted correlations between geomagnetic disturbances and atmospheric pressure. From then on, during the decade of the 1960's investigators in several countries examined the apparent associations among various forms of solar activity, geomagnetic activity and variations in several atmospheric variables, including pressure and temperature.

The general philosophy underlying the use of geomagnetic activity indices for sun–weather investigations is that a sharp increase in magnetic indices is indicative of enhanced solar corpuscular emissions arriving at the earth's environment, disturbing its magnetic and electric field, and its weather. Duell and Duell (1948), showed that within 2–3 days after "geomagnetically disturbed days", in winter months (November through February), surface pressures at European stations fell by an average of 2 hPa, coincident with a rise of equal or greater amount in the Greenland–Iceland area. There is remarkably good agreement in the studies of geomagnetic disturbances with pressure by other authors even though Schuurmans and Oort (1969) dealt with 500 hPa pressure changes following solar flares in the years 1957–1959. Mustel (1972) treated surface pressure winter data associated with magnetic disturbances in the 1890–1967 and Sidorenkov (1974) used winter surface pressure data for the years 1950–1970. Although, the magnitude of the pressure changes is small, a few hundred Pascals, it is the consistency of results between several completely independent studies which is a very promising fact.

Ramakrishna and Heath (1977) have found 10° enhancement in temperature between 35 and 65 kms height following geomagnetic storms. Their study is based on a detailed analy–

sis of 125 soundings at lower altitudes from Wallops Island, Virgina, in 1975. Reiter (1969) found that both potential gradient and air–earth current increased beginning shortly after a solar flare, and peaked 3–4 days afterwards.

Large amounts of evidence have accumulated in the literature, strongly suggesting many aspects of the nature and relationships between solar–geomagnetic activity and the numerous physical parameters involved (Siscoe, 1978).

In the Indian region, work on sun–weather relationships has been dealt mainly in relation to the rainfall and sunspot number (Koteswaram and Alvi, 1969; Bhalme, 1975; Reddy et al., 1980; Bhalme et al., 1981; Reddy and Ramana Murty, 1978). However, studies reported in literature relating to geomagnetic activity with meteorological parameters are very few over the tropics, particularly the Indian region (Bhalme et al., 1981).

To date, none of the physical mechanisms put forth, is conclusive to explain the observed sun–weather relationships and the numerous correlations between solar activity and the meteorological / climatological parameters. One of the physical mechanisms considered responsible for the observed sun–weather relationship is related to the atmospheric electric field (Markson, 1978). Very few studies have been reported to verify the above hypothesis (Poonam Sikka et al., 1988). An attempt has been made to examine the response of atmospheric electric field in association with various meteorological parameters and geomagnetic activity utilizing the long series of good data set of atmospheric electric field recorded at Colaba (18°53′N, 72°48′E, 11m ASL) during the period 1936–1966. The results are presented below.

II. DATA AND ANALYSIS

The data for geomagnetic activity (Ap index), atmospheric electric field and meteorological parameters viz., surface pressure, temperature, relative humidity and wind speed for the period 1936–1966 were used in the present study. The Ap index which is a measure of global magnetic activity is a good indicator of solar activity. The Ap index is derived from the eight 3–hourly Kp values. The dates of onset of geomagnetic storms and corresponding Ap values were extracted from the STP Working Document No. III. A total of 650 geomagnetically disturbed days were observed during the period 1936–1966. Out of these storms, 553 cases were with $Ap < 100$ and 97 cases with $Ap > 100$. The 97 storms with $Ap > 100$ were classified as great geomagnetic storms in the above publication and these were considered in the present study.

The atmospheric electric field data were extracted from the publications of the India Meteorological Department. The atmospheric electric field data were available for the four distinct hours of the day viz., 02–03, 08–09, 14–15, 20–21 hours IST and these data were used in the study. As the original recordings are not available, the present study could only be undertaken with the available data for the four fixed hours of the day. Use of the data derived at the fixed hours of the day may avoid the possible effects of diurnal variation.

The superposed–epoch method has been used to investigate a possible relationship between the geomagnetic activity and atmospheric parameters. The key events are the dates of maximum Ap index of the geomagnetically disturbed days and designated as D_0. Thirteen days surrounded each key event in each single epoch. They ranged from the six days preceeding the event to the sixth day following it. The standard student's t–test was used to test the significance of the results.

III. RESULTS AND DISCUSSION

The response of atmospheric electric field and the meteorological parameters to geomagnetic disturbances (Ap > 100).

1. *Atmospheric Electric Field*

The mean variation in the atmospheric electric field is shown in Figure 1. The electric field steadily increased from zero day onwards and attained a peak on the third day after the zero day. This peak is significant at less than 1 percent level.

2. *Pressure*

The mean pattern of the normalised pressure variations for Colaba, during a 13–day period centered around the geomagnetically disturbed day is shown in Figure 2. It is seen from the figure that the surface pressure started decreasing on the zero day i.e., the day of the occurrence of the great geomagnetic storm and reached a minimum one day after the storm and then it steadily increased to regain its normal level. The decrease is significant at 10 per cent level.

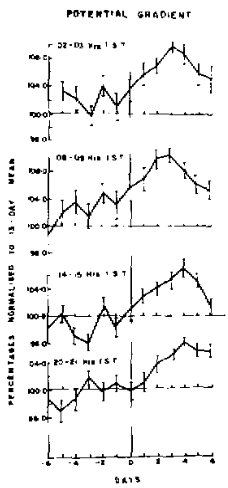

Fig.1. Mean variation of normalized atmospheric electric field for the four different hours of observations. Sample size for each point is 95. 1 cm height of the error bar corresponds to a standard deviation value = 5.0.

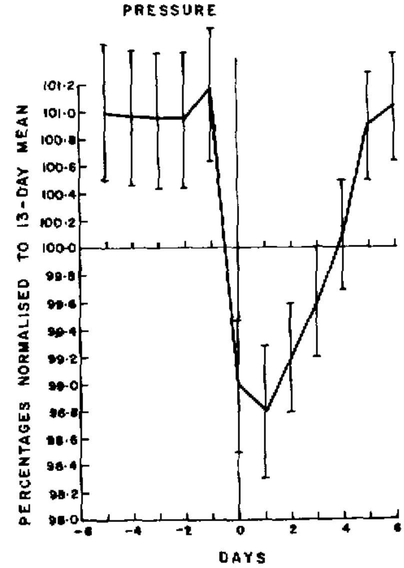

Fig.2. Mean pattern of the normalized pressure variation. Sample size for each point is 97. Scale for indicating the standard deviation is the same as Figure 1.

3. *Wind Velocity*

The mean pattern of the normalised wind velocity variations with respect to great geomagnetic storms is shown in Figure 3. From the figure a decreasing trend in the wind velocity after zero day was observed. The minima on the third day after zero day are significant at 1 per cent level.

4.. Temperature

The mean temperature variation pattern is shown in Figure 4. The temperature increased and peaked about two days after the geomagnetically disturbed day, the peak being significant at less than 1 percent level.

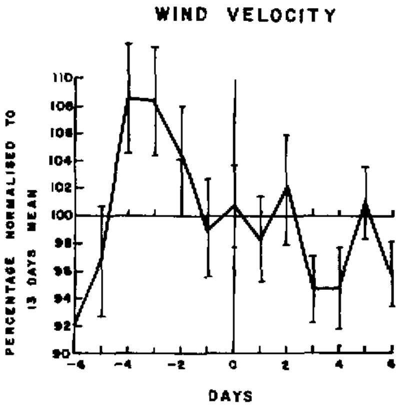

Fig.3. Mean pattern of the normalized wind velocity variations. Sample size for each point is 97. Scale for indicating the standard deviation is the same as Figure 1.

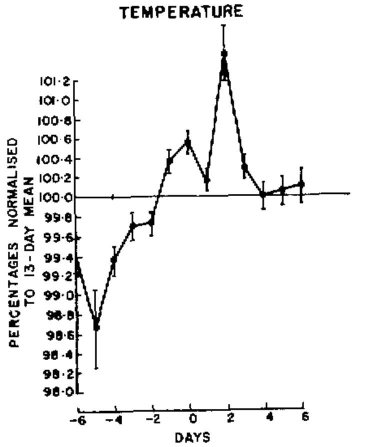

Fig.4. Mean pattern of the normalized temperature variations. Sample size for each point is 97. Scale for indicating the standard deviation is the same as Figure 1.

5. Relative Humidity

Figure 5 shows the mean pattern of the normalised relative humidity variation with respect to the geomagnetically disturbed day. The relative humidity shows a significant decrease (at 10 percent significance level) on zero day and after which it starts increasing and reaches maximum on the fourth day of the event. The peak on the fourth day is significant at 1 per cent level.

Details of the sample size and the standard deviations for each point are indicated in the Figures 1–5. Even though, the actual magnitude of the changes noticed in various parameters is small, the level of significance of the results is found to be high.

Reiter (1969, 1971, 1972), Cobb (1967), Bossolasco et al., (1972, 1973) have investigated the effects of solar flares on the potential gradient. Reiter (1969) found that potential gradient increased beginning shortly after the flare, and peaked 3–4 days afterwards. Cobb (1967) has also reported a peak in the potential gradient 3–4 days after the flare, These results corroborate the results of the present study (Figure 1) and the peak on the third and fourth days after the zero day is significant at one percent level.

The relative humidity increased after zero day and the peak on the fourth day is significant at 1 percent level. Even the temperature increase after zero day reached a peak on the third day. The decrease in wind velocity is in phase with the above parameters as shown in Figure 3.

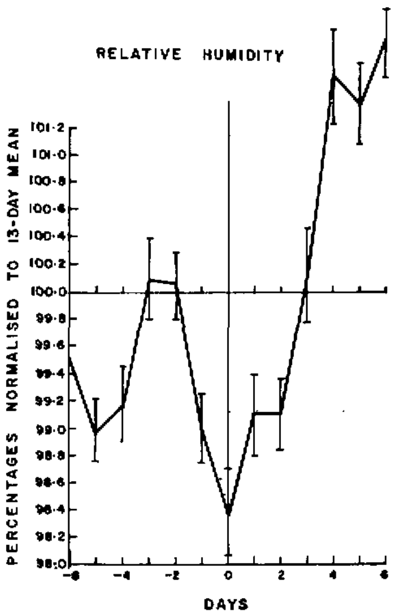

Fig.5. Mean pattern of the normalized relative humidity variations. Sample size for each point is 97. Scale for indicating the standard deviation is the same as Figure 1.

The variations noticed in the potential gradient and pressure appears to start sometime prior to the commencement of the zero day which is the day on which the strength of the storm ($A_p$index) attained its maximum intensity. Similarly the variations noticed in wind, temperature and relative humidity have also a tendency of change (increasing or decreasing) preceeding and succeeding the zero day. Even though it is difficult to delineate the cause and effect relationship between any two parameters, the results presented in Figures 1–5 suggest some relationship among geomagnetic activity, atmospheric electric field and the meteorological parameters studied. Unless, the exact physical mechanisms responsible for the variation of the various parameters are identified, it is difficult to establish a direct relationship between any two parameters. However, investigations relating the effect of geomagnetic activity on atmospheric electric field and meteorological parameters are few and it has been recently recognized that such studies are important for the identification of the physical mechanisms responsible for the sun–weather relationships.

A possible simple mechanism has been put forth to explain the responses of meteorological parameters and atmospheric electric field to geomagnetic activity in the present study.

Recent experimental investigations relating to electrical coupling between troposphere –ionosphere and magnetosphere suggest the possible solar modulation of atmospheric electri–fication.

A physical hypothsis for the electrical coupling of the troposphere–ionosphere and magnetosphere has been proposed (Poonam Sikka et al., 1988). It is shown that a vertical mass exchange takes place in the troposphere–ionosphere and magnetosphere by the gravity wave feedback mechanism through a chain of eddy systems. The vertical mass exchange gives rise to vertical aerosol current which is responsible for the generation and maintenance of atmospheric electric field and also variations in the H–component of the geomagnetic field. Any perturbations in the troposphere would be transmitted to the ionosphere and vice–versa. Any global perturbation in the ionosphere as the one caused by solar variability is transmitted to the troposphere, influencing weather systems, and geomagnetic / atmospheric electrical processes. The above physical hypothesis appears to explain the variations noticed in the atmospheric electric field and meteorological parameters following the geomagnetic storms.

However, other factors involving temporal lag between the solar flares and the variations noticed in the atmospheric electric field and the meteorological parameters need to be explained and further studies in this direction are required for verifying the above hypothesis.

IV. CONCLUSIONS

The association among the atmospheric electric field and meteorological parameters recorded at a tropical coastal station during the period 1936–1966 and the geomagnetic activity ($A_p > 100$) suggested the following:

1) The atmospheric electric field during winter (November–February), pre–monsoon (March–May) and post–monsoon (September–October) seasons showed significant increase (at 1 per cent level) from the zero day and attained a peak on the third day after the epoch day.

2) The surface pressure showed a decrease from zero day onwards and reached a minimum value one day after the epoch day.

3) The wind velocity showed a decrease after zero day and the minima on the third day after the epoch day are significant (at 1 per cent level).

4) The temperature showed a significant increase (at 1 per cent level) and reached its peak value two days after the zero day.

5) The relative humidity showed a decrease on zero day and reached its maximum on the fourth day of the event (significant at 1 per cent level).

The variations noticed in the meteorological parameters, namely, decrease in pressure and wind, increase in temperature and humidity, appear to be consistent with the increase in the electric field for the following reasons.

Increases noticed in the temperature and humidity would indicate enhanced convective activity which would give rise to increase in the atmospheric electric field. The above variations are consistent with the physical hypothesis discussed in the above section. Even though the above conclusions are based on observations recorded at a single location, such responses on a global scale cannot be ruled out. Further investigations to verify the above hypotheses would be required.

I wish to express my sincere thanks to Dr. A. S. R. Murty and Dr. A. M. Selvam for their continuous encouragement and valuable suggestions during the course of this study.

REFERENCES

Bhalme, H. N. (1975), *Indian J. Met. Hydrol. Geophys.* **26:** 55.

Bhalme, H. N., R. S. Reddy , D. A. Mooley and Bh. V. Ramana Murty (1981), Solar activity and Indian weather / climate, *Proc. Indian Acad. Sci.* (Earth Planet. Sci.), **90:** 245–262.

Bossolasco, M., I. Dagnino, A. Elena, and G. Flocchini (1972), Solar flare control of thunderstorm activity, in Studi in onore di G. Aliverti, *Instituto Unversitario Navale Di Napoli,* pp. 213.

Bossolasco, M., I. Dagnino, A. Elena, and G. Flocchini (1973), The thunderstorm activity over the Mediterranean area. *Rivista Italiana di Geofisca* (cont of Geofisice E Meteorologia), **12:** 293.

Cobb, W. E. (1967), Evidence of a solar influence on the atmospheric electric elements at Mauna Loa Observatory, *Mon. Wea. Rew.*, **95:** 12.

Duell, B. and G. Duell (1948), The behaviour of atmospheric pressure during and after solar particle invasions and solar ultraviolet invasions, *Smithsonian Misc. Collection* **110:** 8.

Koteswaram, P. and S. M. A. Alvi (1969), *Curr. Sci.*, **38:** 229.

Macdonald, N. J. and W. O. Roberts (1960), Further evidence of a solar corpuscular influence on large–scale circulation at 300 mbar, *J. Geophys. Res.*, **65:** 529.

Markson R. (1978), Solar modulation of atmospheric electri–fication and possible implications for the sun–weather relationship, *Nature*, **273:** 103–109.

Mustel, E. R. (1972), On the reality of the influence of solar corpuscular streams upon the lower layer of the earth's atmosphere, Publ. No.24, *Astronomical Council. USSR Acad. of Sciences*, Moscow.

Pittock, A. B. (1978), A critical look at long term sun–weather relationships, *Rev. Geophys. Space Phys.*, **16:** 400–420.

Ramakrishna, S. and D. F. Heath (1977), Temperture changes associated with geomagnetic activity at Wallops Island, *Eos* **58:** 696.

Reddy, R. S. and Bh. V. Ramana Murty (1978), *Indian J. Radio Space Phys.*, **7:** 215.

Reddy, R. S., S. S. Parasnis and Bh. V. Ramana Murty (1980), *Advances in Space Exploration*,COSPAR Symp. Series, Oxford, U. K.

Reiter, R. (1969) Solar flares and their impact on potential gradient and air–earth current characteristics at high mountain stations, *Pure Appl. Geophys*, **72:** 259–267.

Reiter, R. (1971), Further evidence for impact of solar flares on potential gradient and air–earth current character–istics at high mountain stations, *Pure Appl. Geophys*, **86:** 142–158.

Reiter, R. (1972), Case study concerning the impact of solar activity upon potential gradient and air–earth current in the lower troposphere, *Pure Appl. Geophys.*, **94:** 218–225.

Schuurmans, C. J. E. and A. H. Oort (1969), A statistical study of pressure changes in the troposphere and lower strat–osphere after strong solar flares, *Pure Appl. Geophys.*, **75:** 233–246.

Shapiro, R. A. (1954), A possible solar weather effect, *J. Meteorl.*, **11:** 424.

Sidorenkov, N. S. (1974), Solar corpuscular streams and weather on the earth (English Trans.), Rpt. NO. JPRS 62197, Joint Publications Research Service (available from Natl. Tech. Info. Service, Springfield, Va.), pp 21.

Sikka, P., A. Mary Selvam and A. S. Ramachandra Murty (1987), Possible solar influence on atmospheric electric field, *Adv. Atmos. Sci.*, **5** (2): 217–228.

Siscoe, G. L. (1978), Solar–terrestrial influences on weather and climate, *Nature*, **276:** 348.

Taylor (Jr.), A. G. (1986), Selective factors in Sun–weather research,*Rev. of Geophys.* , **24:**(2) 329.