Solar-geomagnetic-climatic Relationships at Bombay

B J SRIVASTAVA, HABIBA ABBAS & SUBHASH SAXENA
National Geophysical Research Institute, Hyderabad 500 007

Received 29 May 1979

Geomagnetic and meteorological data consisting of annual mean values for the period 1848-1967 from Colaba and Alibag Observatories, Bombay, situated on the sea-coast in the tropics and under the strong influence of the Indian monsoon, are studied and their long-period variations examined against similar trends in the corresponding annual mean sunspot numbers. The increasing secular trend of the geomagnetic total intensity at Alibag appears to be inversely related to the surface atmospheric pressure trend and directly to the air temperature and the annual total rainfall trends at Colaba, contrary to the results given by some workers for various other stations around the world, particularly in the higher latitudes. Climatic modulations, if any, due to the geomagnetic secular variation in the Indian region are greatly influenced by the local monsoon and other environmental conditions. Alternatively, the observed geomagnetic and climatic changes over long periods may be treated as two independent effects of solar activity.

1. Introduction
Solar-terrestrial relationships have been investigated by various workers over the past hundred years or so, and rather vigorously on a multi-disciplinary basis since the IGY (1957-1958). Wollin et al. found that the trends in the geomagnetic total intensity \( F \) at most of the magnetic observatories in the world correlate negatively with the trends of 10-yr means of the air temperature from the nearby weather stations. King also observed that the winter temperatures for central England and the annual rainfall for England and Wales for the period 1900-1970 are inversely related to the secular variation trend of the geomagnetic total intensity at Eskdalemuir and Stonyhurst in Great Britain. The coldest areas on the surface of the earth exist around the north and the south magnetic poles, where the magnetic intensity values are highest. Bucha has discussed correlations between palaeomagnetic data from lake sediments and climatic (temperature) changes over the past 400,000 years, and also between the daily geomagnetic activity indices and atmospheric pressure changes at 500 mb level over the geomagnetic poles and temperature deviations from the normal at Prague for a period of few months.

In this paper, the long series of geomagnetic and meteorological data collected at the Colaba and Alibag Observatories, Bombay, situated in the tropics and under the strong influence of the Indian monsoon, have been studied against the annual mean sunspot numbers, and their interrelationships discussed.

2. Data
The Meteorological Observatory at Colaba, Bombay (geogr. coord: 18°54'N, 72°49'E), has been in continuous operation since 1826. The magnetic observatory at Colaba (1846-1905) was shifted to Alibag (geogr. coord: 18°38'N, 72°52'E), 29 km south-south-east of Bombay, in 1904, and comparative observations were made at both the stations during 1904 and 1905 which provided the site corrections for reducing the old Colaba magnetic data to Alibag site. The Alibag annual mean values of \( H \) and \( Z \) for Colaba-Alibag (1848-1946) were taken from the tables given by Pramanik, where the Colaba data up to 1905 had been reduced to Alibag. The Alibag annual mean magnetic values for 1947-1973 were taken from the Observatory's year-books. The annual mean values of \( F \) at Alibag were then computed from the corresponding \( H \) and \( Z \) values for the years 1848-1973.

The annual mean values of atmospheric pressure (reduced to standard gravity at 45°N latitude, mean sea level and 0°C), the annual total rainfall at Colaba (1848-1967), and the air temperature (dry bulb) (1878-1967), as observed at Colaba at
Let us now examine the plots of the available annual mean values of the meteorological elements (pressure, temperature and total rainfall) at Colaba, Bombay, for the same period (Fig. 1). The trend lines for the three sets of data are shown by means of broken lines passing through the 11-yr mean values (solid circles) in Fig. 1, which reveal the long-period variations. The trend line for atmospheric pressure variation at Bombay shows a maximum around 1875 and a minimum around 1950 in a phase opposite to that of the geomagnetic intensity at Alibag, giving roughly a cycle of about 150 years.

The increasing trend of the air temperature at Bombay from 1878 to 1967 is directly related to the increasing trend of the geomagnetic total intensity at Alibag, contrary to the results given by Wollin et al. 13 and King, 4 who found a decrease in the geomagnetic intensity associated with an increase in the air temperature and an increase in the rainfall, and vice-versa.

The plot of annual total rainfall data of Colaba, Bombay for the years 1848-1967 (Fig. 1) shows the trend line with nearly an 80-yr cycle. The increasing trend in the rainfall data from 1910 to 1967 is in phase with the increasing trend of the geomagnetic intensity at Alibag. Considering the overall climatic picture of increasing temperature, decreasing pressure and increasing rainfall at Bombay (the sequence fits in meteorologically), the data appear to be associated with the increasing secular trend of the geomagnetic total intensity at Alibag. This reversed climatic trend at Bombay in relation to the geomagnetic intensity trend as compared to various other stations around the world, 1 shows the strong influence of the Indian monsoon and other local conditions on the climatic data recorded at Bombay.

Jagannathan and Parthasarthy 14 studied the secular trends in the mean annual surface air temperatures at eight widely separated stations (both coastal and inland) in India (Fort Cochin, Bangalore, Madras, Hyderabad, Bombay, Nagpur, Calcutta and Allahabad), for the period 1875-1968, and found an increasing trend at Calcutta, Bombay, Bangalore and Allahabad; no significant trend at Hyderabad and Madras; and a decreasing trend at Fort Cochin and Nagpur. For the same period, the geomagnetic total intensity showed an increasing trend over the region at Alibag (Fig.1), Dehra Dun and Kodaikanal. 15 Thus, the geomagnetic intensity trend in the Indian region does not appear to have any definite relationship with the temperature trends in the different parts of the country. It is quite possible that geomagnetic and climatic changes over
Fig. 1 — Plot of the annual mean values of the Zurich sunspot numbers, the geomagnetic total intensity at Alibag together with its residuals from the trend, the meteorological elements (surface pressure, air temperature and total rainfall) at Colaba, Bombay, together with their 11-yr mean values, indicating the trends for all the available years during 1845-1975.
long periods reflect two independent effects of solar activity duly modified by local environmental conditions.

Rangarajan\textsuperscript{16} reported a very interesting aspect of the seasonal variation of atmospheric ozone in India, regarding the reversal of the latitudinal gradient of total ozone during the monsoon season (June-Sep.) which leads to higher ozone in the south including Ahmedabad and Kodaikanal, than in the north, attributable to variations in the tropopause height. The higher ozone in the south may give rise to higher air temperatures at the ground level.

The main cause of the long-period variations of the geomagnetic intensity and the meteorological parameters appears to be the presence of the different cycles (11-yr, 22-yr, 95.8-yr and 179-yr) in the sunspot numbers\textsuperscript{17} which are a measure of the solar and geomagnetic activity. These cycles together with changes in the effective solar constant and local physical conditions, influence the climate and the factors responsible for the geomagnetic secular variation inside the earth’s liquid core, possibly through the fluctuations in the equatorial ring-current around the earth.\textsuperscript{18}

Acknowledgement

The authors are indebted to the Deputy Director-General of Observatories (Climatology and Geophysics), India Meteorological Department, Pune, for providing the long series of meteorological data of Colaba (Bombay), and to Dr V Venkateswarlu, Chief Meteorologist, Meteorological Office, Hyderabad, for making available part of the meteorological data used in this investigation. Grateful thanks are also due to the Director, N.G.R.I., for encouragement of interdisciplinary studies in Geophysics, and also for permission to publish this paper.

References