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Global geomagnetic impulses in annual intensity changes

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Abstract. The global character of four recent geomagnetic impulses has been critically examined, particularly in the horizontal component annual mean values and the year-to-year differences, at several observatories in three longitude zones around the world, with special emphasis on Indian and other low latitude stations. All the prominent geomagnetic impulses in the horizontal intensity, observed at Colaba and Alibag observatories during 1848–1980, are also studied and their correlation with the annual mean sunspot numbers and their changes discussed. The global character of most of the impulses recorded during the period 1940–1977 is established with the help of data from world-wide observatories.

It is concluded that these impuleses in the geomagnetic field are quite frequent and form part of the geomagnetic field variation spectrum with time, attributable to solar cycle effect. They evidently originate in the fluctuations of the magnetospheric ring current caused by periodic solar activity.

Key words: Geomagnetic impulses – Annual changes – *H*, *Z* components – Sunspot numbers – Ring current

Introduction

In recent years, several papers have appeared on the subject of impulses in geomagnetic secular variation lasting one or two years, and their causes – external or internal (Mizuno, 1980; Achache et al., 1980; Nevanlinna and Sucksdorff, 1981; Alldredge, 1981, 1982; Malin and Hodder, 1982). These impulses are best seen in the plots of the annual changes of the horizontal intensity at low and middle latitude stations. Nevanlinna and Sucksdorff (1981) studied the global secular variation impulse of 1977–1979, showing large enhancements in the year-to-year changes in the vertical component in 1978 at the European observatories, and demonstrated, with the help of *H* and *Z* changes at some 30 world-wide observatories, that the pulse was of external origin caused by an intensification of the magnetospheric ring current system lasting about two years, due to an increase in solar activity. Moos (1910) was among the very early workers who demonstrated the influence of the 11-year solar cycle on the annual mean values of the geomagnetic elements at Bombay.

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Mizuno (1980), on the other hand, examined the impulsive changes of 1965 and 1974 with the help of the geomagnetic data recorded in Japan, and described them as regional secular variation features attributable to internal causes, depicting a transition from one stable state to another. He further noted that neither of the impulses was of global or zonal distribution. Achache et al. (1980) demonstrated the occurrence of a global secular variation impulse between 1969 and 1970 from an analysis of the geomagnetic data from world observatories and estimated that the average conductivity of the lower half of the mantle does not exceed 150 Ω^{-1} m^{-1}, which agrees well with the earlier estimates of Runcorn (1955) and Banks (1969), but is several orders of magnitude smaller than the values of 1,000 Ω^{-1} m^{-1} as given by Alldredge (1977) and Stacey et al. (1978). Malin and Hodder (1982) further analysed and studied the global geomagnetic jerk of 1970 and confirmed that it was predominantly of internal origin.

In this paper, we attempt to establish the global character of the four recent impulses of 1965, 1970, 1974 and 1977, in the horizontal component *H* in three longitude zones at 26 observatories with special emphasis on the data from the Indian and other low latitude observatories. We also examine all the prominent impulses in the horizontal intensity as observed at the Colaba and Alibag observatories in India during 1848–1980, and at fourteen world-wide observatories in *X* during 1940–1977, and their relationship with the annual sunspot numbers.

Data

The annual mean values of the horizontal intensity *H* at Colaba-Alibag (1848–1946) were taken from the tables given by Pramanik (1952), where the Colaba data up to 1905 had been reduced to the Alibag site, by applying appropriate corrections. The Alibag annual mean values for the years 1947–1980 were taken from the Observatory's yearbooks and the recent Indian Magnetic Data volumes. The annual mean values of the north component *X* at Apia, Eskdalemuir, Fürstenfeldbruck, Gnangara, Godhavn, Hermanus, Honolulu, Huancayo, Kakioka, Meanook, Pilar, Tucson, Yakutsk and Yangi-Bazar for the period 1940–1973, were taken from the tables given by Yukutake et al. (1979), and of *X* and *H* for the remaining years from the IZMIRAN summary of annual mean values (Orlov and Ivchenko, 1971; Pushkov and Ivchenko, 1972–1980). The annual mean values of the Zürich relative sunspot numbers

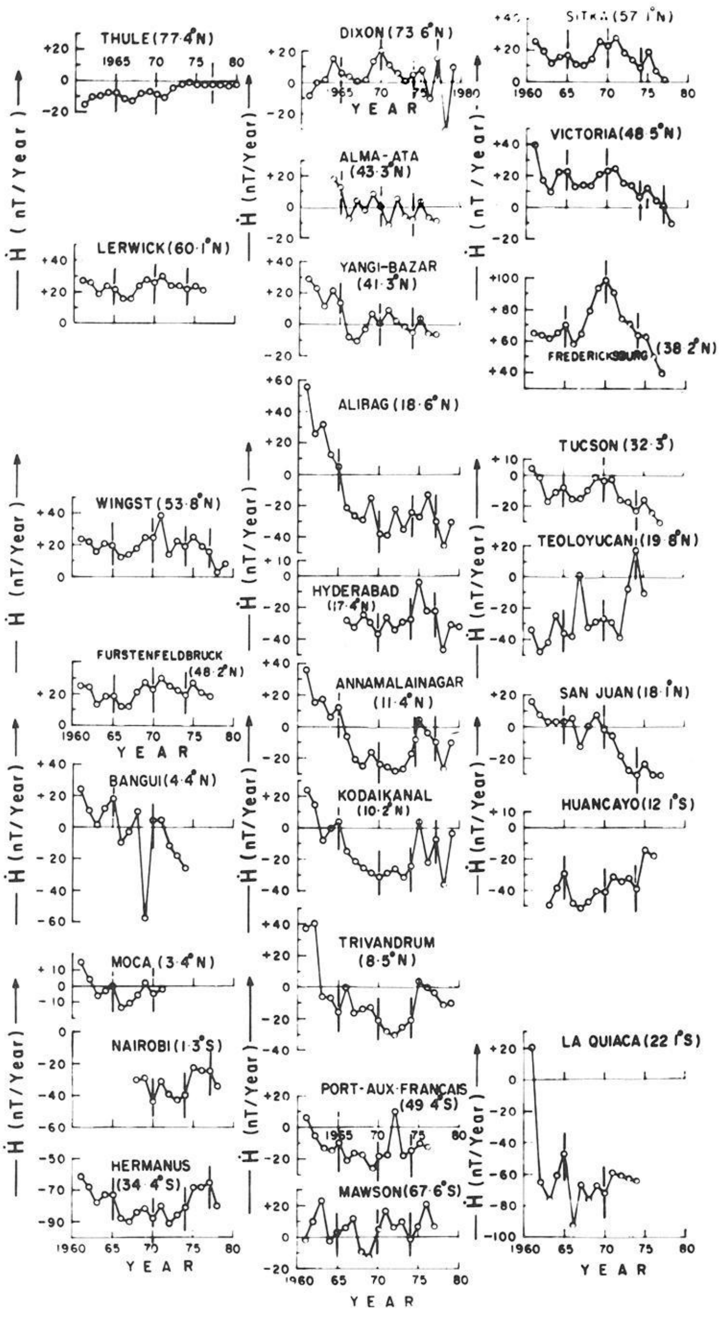

Fig. 1. Plots of the annual changes in the horizontal intensity *H* of the geomagnetic field at world observatories in three longitude zones during 1960–1980. Note the geomagnetic impulses of 1965, 1970, 1974 and 1977 and their global character. Annual changes in the sunspot numbers are shown in Figs. 3 and 4, for the same period, to show their association with the occurrence of the impulses

were abstracted from the tables given by Kiepenheuier (1953), and relevant volumes of Journal of Geophysical Research (AGU, U.S.A.) and Solar-Geophysical Data volumes, published by World Data Center A for Solar-Terrestrial Physics, NOAA, Boulder, Colorado, USA.

Analysis and discussion

The year-to-year changes in the annual mean values of *H* at the various observatories were computed and plotted against the year, in order to bring out the impulses much more prominently than in the plot of the annual mean values themselves. The year-to-year differences in the annual mean Zürich sunspot numbers were also computed and plotted for a possible correlation with the magnetic impulses.

Figure 1 shows the character and amplitude of the 4 recent impulses of 1965, 1970, 1974 and 1977 in the horizontal component at several stations around the world in three longitude zones.

The impulses of 1965 and 1977, following the sunspot minimum years (1964, 1976) are of negative sign, while the impulse of 1970 corresponding to the solar maximum (1968–1970) and that of 1974 preceding the sunspot minimum year (1976) are of positive sign. Figure 1 demonstrates unmistakably the global character of these 4 impulses. Mizuno (1980), however, thought that the apparent secular variation impulses of 1965 and 1974 were regional in character and were of internal origin. Rather than the impulse of 1965, Srivastava and Habiba Abbas (1977) pointed out the reversal of the secular variation trend in the India-Japan region after 1965, as an important regional feature, con-

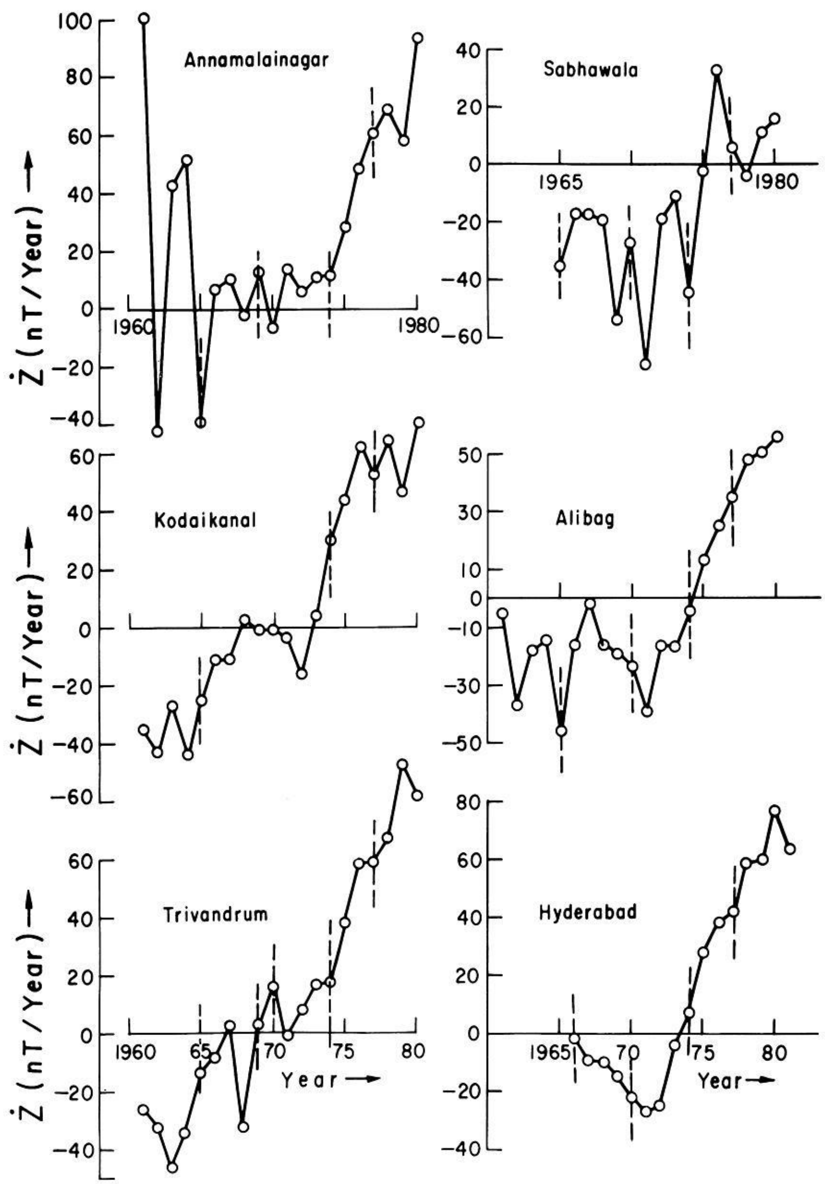

Fig. 2. Year-to-year changes in the vertical component Z of the geomagnetic field at the Indian stations during 1960–1980, showing the small amplitudes of the impulses at low latitudes. Some spikes occurring before 1970 are probably due to inaccuracies in baseline measurements. Note the steadily increasing changes in Z due to the southward drift of the dip equator in India since 1967

nected with a southward migration of the dip equator in India from 1967, this being part of an 80-year cycle of secular variation of internal origin. But the apparent impulses of 1965 and 1974 are now clearly found to be of global character (Fig. 1), and are associated with large annual rates of change of the sunspot numbers in the opposite sense. They are therefore of external origin due to changes in the westward ring current caused by the abrupt changes in the solar activity near the minimum and maximum of the 11-year solar cycle. The inverse relationship of these apparent impulses with the rates of change of sunspot numbers has been discussed by Alldredge (1982) who pointed out that the sudden increase in sunspot numbers result in a sudden increase in the westward ring current and cause a sudden decrease in the X or H component, and vice versa.

Nevanlinna and Sucksdorff (1981) demonstrated large and positive Z-changes at north European observatories in high latitudes during the secular variation impulse of 1977, corresponding to negative H-changes, which are the largest at the equator, and further concluded that the impulse was of external origin and part of the solar cycle effect. Figure 1 confirms the global character of this impulse as also of the 1965, 1970 and 1974 impulses, and shows the changes observed in H at both low and high latitudes.

The signatures of these four impulses in the vertical component at the Indian stations are shown in Fig. 2. It will be at once noticed that these changes in Z at low latitudes are rather small, although they are quite prominent and large at high latitudes. A few large impulses in Z at Annamalainagar and Sabhawala are probably due to inaccuracies in baseline measurements.

Another noteworthy feature of Fig. 2 is the steadily increasing character of the annual Z changes in India in recent years, which has been linked with the southward drift of the dip equator in India since 1967, as part of its 80-year secular cyclic oscillation (Srivastava and Habiba Abbas, 1977).

Figure 3 gives a plot of the annual changes in the northerly component X at several stations in three longitude zones for the period 1940–1977. A number of impulses can be identified which are of global character. Their inverse

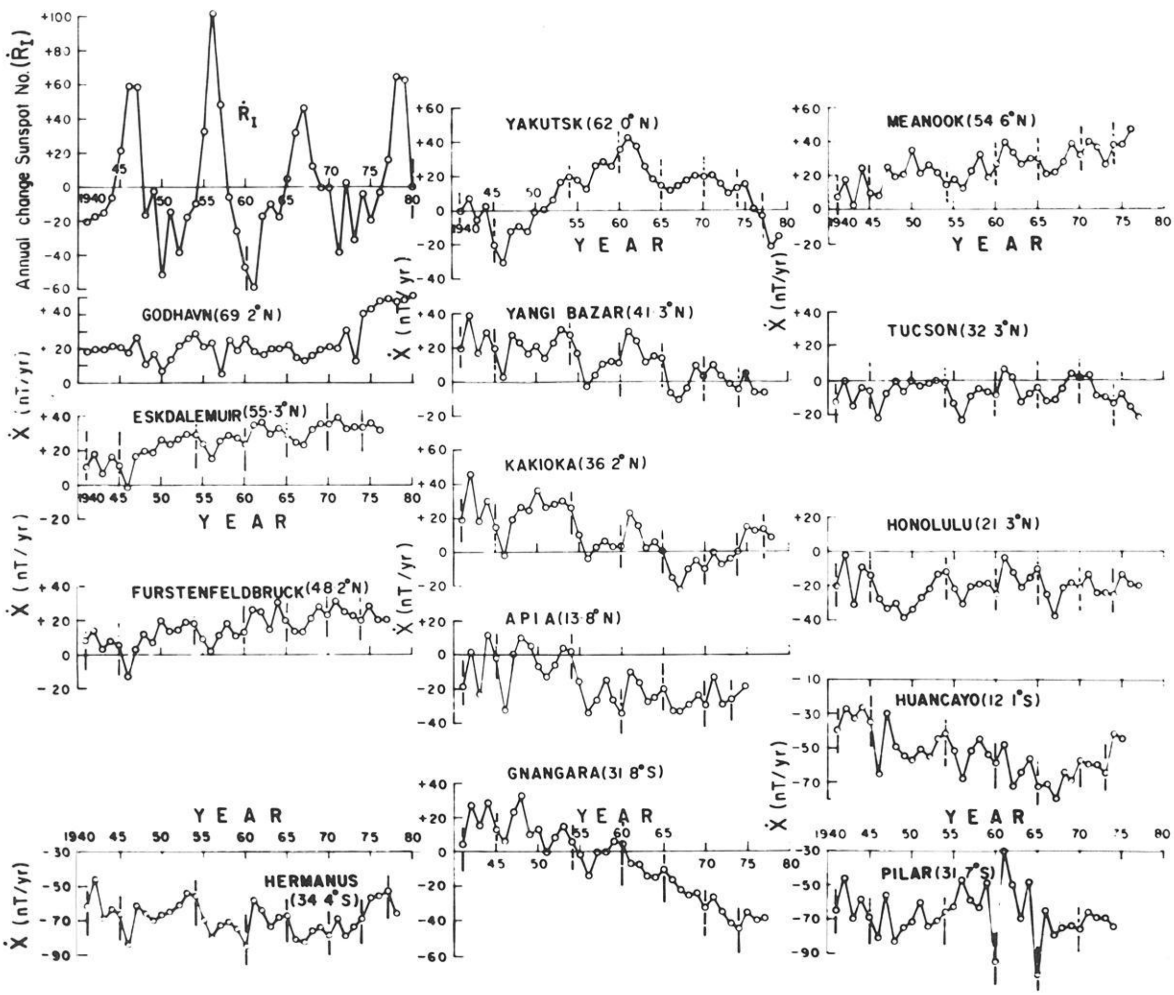

Fig. 3. Plots of the annual changes in the northerly component X of the geomagnetic field at world observatories in three longitude zones during 1940–1977. Note the global character of seven geomagnetic impulses indicated by vertical dotted lines. Annual changes in the sunspot numbers are also shown and the association of large positive and negative changes with the impulses can be clearly seen

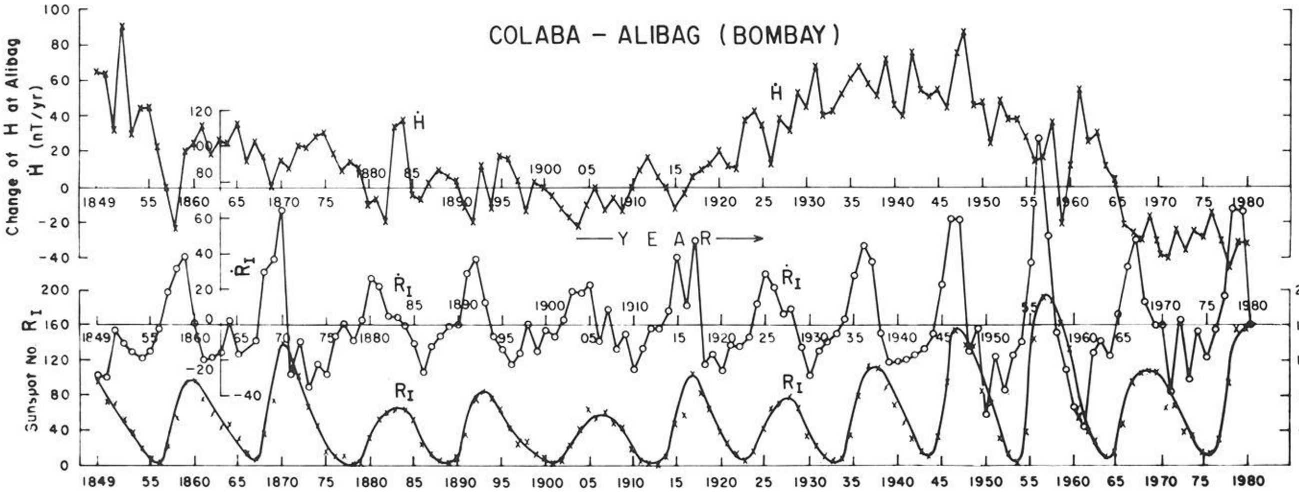

Fig. 4. Year-to-year changes in the geomagnetic horizontal intensity at Colaba and Alibag observatories, Bombay (India) during 1848–1980, the corresponding annual changes in the sunspot numbers, and the annual mean Zurich sunspot numbers R_I for the same period, showing the occurrence of geomagnetic impulses with a periodicity of about 5 years, being part of the 11-year solar cycle effect

association with large annual changes in the sunspot numbers (Fig. 3) is also remarkable. The impulses which are not global could arise from local causes or observational errors.

Figure 4 shows the annual changes of H at Colaba and Alibag (Bombay), India, during 1848–1980, along with the annual changes in the sunspot numbers as well as the annual mean Zürich sunspot numbers.

Several prominent impulses, both positive and negative, can be readily seen and their inverse association with the rate of change of the annual sunspot numbers can also be noticed. It is, however, not possible to give an empirical quantitative relationship between the rate of change of the annual sunspot numbers and the amplitudes of the impulses in H at different observatories. It is quite possible that the areas of sunspots and other solar activity centres are also involved in these correlations.

It appears that these geomagnetic impulses are quite frequent and form part of the spectrum of the geomagnetic field variation over 2–11 years as discussed by Currie (1973), and are attributable to the solar cycle effect.

Conclusions

Geomagnetic impulses of 1965, 1970, 1974 and 1977, in H, have been demonstrated to be of global character, occurring in association with rapid changes in the annual mean sunspot numbers near the minima or maxima of the 11-year solar cycle. Several impulses have also been identified during the period 1940–1977, at world-wide stations, in the annual changes of the X component of the geomagnetic field, and associatied with large increases or decreases in the annual sunspot numbers. In the case of the annual changes in the long series of H component data at Colaba and Alibag observatories, Bombay (India) for the period 1848–1980, most of the impulses, once again, are found to occur in inverse association with large and abrupt changes in the sunspot numbers, and reveal a periodicity of 5 years. A quantitative relationship between the amplitudes of the impulses and the annual changes in the sunspot numbers is, however, not possible, because the areas of sunspots and other solar activity centres may also be involved in these correlations.

It is emphasised that these apparent impulses are of external origin and are generated by changes in the westward magnetospheric equatorial ring current following the changes in the 11-year solar cycle.

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