Equatorial Enhancement of DP2 Fluctuations

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The fluctuations of geomagnetic H at the equatorial location Huancayo and the low latitude location Fuquene at the same longitude were compared during two DP2 events. It was seen that, in contrast to the usual belief that these fluctuations are enhanced in the electrojet region in the same way as the enhancement of normal Sq , the fluctuations were either abnormally enhanced or erratic in the morning hours before the electrojet maximum. Thus, some other factors besides the electrojet current strength (probably peculiar irregularities) seem to be involved in causing these equatorial enhancements.

1. Introduction

Besides SSC and SI, there are other short-term fluctuations in the geomagnetic field which are world-wide in nature but have enhanced magnitudes in the equatorial electrojet region (NISHIDA and JACOBS, 1962; ONWUMECHILI, 1960; ONWUMECHILI and OGBUEHI, 1962). Often, these appear as a train of several peaks, about 1/2 hour to few hours apart and are reported to be associated with fluctuations of the B_z component of IMF, Interplanetary Magnetic Field (NISHIDA, 1968 a, b; RASTOGI and PATEL, 1975). From a few selected events, NISHIDA (1968 a, b, 1971) reported that the fluctuations at the equatorial locations Kodaikanal (75°E) and Huancayo (75°W) were about 4 times larger than those at the corresponding low latitude locations Alibag and Fuquene (respectively) outside the electrojet region, and, also, that this ratio was larger than the ratio 2 usually obtained for SSC events, indicating that whereas SSC had a contribution partly from the magnetosphere and partly from the ionosphere, the DP2 was largely of ionospheric origin. ONWUMECHILI and OGBUEHI (1962) reported that the amplitude decreased rapidly, away from local noon and dip equator. From the world-wide distribution of amplitudes, NISHIDA *et al.* (1966) and NISHIDA (1968 a, b) envisaged an overhead ionospheric current system as shown in Fig. 1, consisting of two vortices, one in the morning side and another in the evening side, and a zonal flow in the equatorial region, with the morning vortex terminating somewhere about 20–30° latitude and giving way to the zonal flow. It would thus

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Fig. 1. Equivalent current system in the overhead ionosphere, envisaged to explain the world-wide distribution of DP2 fluctuations (NISHIDA, 1968b).

seem that the equatorial enhancement is envisaged to be of the same nature as the enhancement of Sq in the dip equator region by the mechanism suggested e.g. by BAKER and MARTYN (1953).

The DP2 type fluctuations are frequent during high sunspot years. However, fluctuations exceeding 100 gamma at Huancayo are rare. In this communication, we illustrate some odd features of the equatorial enhancement during two such large events, selected out of about half a dozen that occurred in the last 10 years.

2. Event of April 9, 1971

Figure 2 shows a plot of values of H taken at 10 min intervals at Fuquene (6°N , 74°W , geomag. lat. $+16.9^{\circ}$, full lines) and Huancayo (12°S , 75°W , geomag. lat. -0.6° , dashed lines) for 0–24 hours (UT) of Apr. 9, 1971. The LT (75° WMT) is also indicated at the top. The H components have absolute magnitudes of about 29,000 gamma at these locations. For plotting, appropriate base values have been subtracted so that the starting values (0000 UT) are near zero gamma and the values match exactly at about 0120 LT when the night-time maximum occurred. The first 12 hours correspond to 19–07 LT and are thus during night-time when, normally, one would expect steady levels of H . However, there are fluctuations as large as 100 gamma indicating that the period was stormy. This is confirmed by the plot of Dst and of IMF B (total component) and the horizontal black lines indicating the presence of negative θ for IMF, which signify the initiation of a storm at about 05–06 UT. However, the

Fig. 2. Traces of the H component at Fuquene (full lines) and Huancayo (dashed lines) for April 9, 1971. Geomagnetic Dst and interplanetary B are also shown. For IMF (θ) horizontal black lines indicate negative θ .

traces of H at Huancayo and Fuquene are almost coincident upto 1200 UT (0700 LT) indicating that the fluctuations were due to far-away ring currents.

From 0700 LT onwards, Huancayo shows violent fluctuations, with a train of eight peaks in the next 7 hours. Figure 3 shows the traces on an elongated scale for only the 9 hour interval 1100–2000 UT (0600–1500 LT). The scale for Huancayo H

Fig. 3. H component at Huancayo and Fuquene as also IMF- B , θ , ϕ for 1100–2000 UT on Apr. 9, 1971 when a train of DP2 fluctuations occurred. Note that the scale for Huancayo (H) is 2.5 times compressed as compared with Fuquene (H).

Fig. 4. Huancayo (H) versus Fuquene (H) for the event of April 9, 1971. Different symbols represent different LT intervals and bracketed numbers near the regression lines represent slopes, i.e. ratios of the fluctuations of Huancayo (H) to those of Fuquene (H).

is compressed by a factor of 2.5 as compared with that of Fuquene. Interplanetary magnetic B , θ , ϕ are also shown. Some oddities are obvious. Thus, the fluctuations at Huancayo and Fuquene are not of a constant ratio. Also, even though B is large, there are no clear-cut peaks in interplanetary θ similar to those in Huancayo H . However, we do not intend to investigate its relationship with IMF in any further detail in this communication.

To study the interrelationship between variations of H at Huancayo and Fuquene, we plot in Fig. 4 H (Huancayo) versus H (Fuquene), showing different LT by different symbols. The magnitudes used are those of Fig. 2, with 150 gamma added to Huancayo and 100 gamma added to Fuquene. To avoid confusion and congestion, not all pairs of 10 min values are used, but only selected ones, specially those representing points of inflexion (sudden changes). The full circles refer to the first 12 hours (UT) i.e. for 1900–0700 LT (i.e. night-time) and seem to fall very well on a straight line of slope about 1.2, consistent with a non-ionospheric (magnetospheric) source with a roughly $\cos \theta$ latitude dependence. The open circles refer to the next 100 minutes (0710–0850 LT) and the points deviate very violently from the night line showing nearby ionospheric contributions. A new regression line through them shows a slope as large as 15.0. The open squares referring to the next two hours (0900–1050 LT) and the crosses for the next $1\frac{1}{2}$ hour (1100–1230 LT) seem to fall on another straight line of a lesser slope viz. 7.0. Thus, the peak slope was not at about 1000–1100 LT when the equatorial electrojet is supposed to attain its maximum strength, but much earlier

at about 0800 LT. The afternoon points represented by crosses inside circles (1240–1530 LT) fall on another straight line of a lesser slope 5.0 (indicating decreased ionospheric effects) and the points for the next $1\frac{1}{2}$ hour (full squares inside circles, 1540–1700 LT) have a still lesser slope 3.7 till finally the evening points (1710–1900 LT, full squares) have a slope of only 1.3 and almost merge with the earlier night lines (full dots, slope 1.2) showing a return back to magnetospheric effects. It would thus seem that, for this event, during hours *before* the normal electrojet maximum at about 1100 LT, the fluctuations at Huancayo attained very large magnitudes as compared with those at Fuquene.

Fig. 5. Traces of the H component at Huancayo, Fuquene, San Juan, Fredericksburg and Boulder for 1200–2100 UT on Sep. 19, 1977. B , θ , ϕ in the earth's magnetosheath are also shown. Local times are indicated on each curve separately.

3. Event of September 19, 1977

Figure 5 illustrates another event, of Sep. 19, 1977. This was also a stormy day with the main phase of the storm starting at about 12 UT. Only H traces for the period 1200–2100 UT are shown for several locations viz. Huancayo (12°S , 75°W , geomag. lat. -0.6°), Fuquene (6°N , 74°W , geomag. lat. $+16.9^\circ$), San Juan (18°N , 66°W , geomag. lat. 29.6°), Fredericksburg (38°N , 78°W , geomag. lat. $+49.6^\circ$) all at about the same longitude and at Boulder (40°N , 105°W , geomag. lat. $+48.9^\circ$) about 30° to the west of Fredericksburg. Violent fluctuations occurred in the early morning hours. However, the fluctuations at Huancayo are not parallel to those at Fuquene. In fact, between 12–13 UT which is 07–08 LT for both, the patterns are reversed. If interpreted in terms of the morning vortex of Fig. 1, this would imply that Fuquene and Huancayo are on opposite sides of the morning focus. NISHIDA (1968b) has attempted to explain the twin-vortex system of Fig. 1 on the basis of an electric field $E = -(1/c) [U \times B]$ where U = solar wind velocity and B = total IMF so that fluctuations of B_z from north to south would result in increases in geomagnetic H and fluctuations from south to north would result in decreases. There are some theoretical difficulties for such an external electric field to penetrate the magnetosphere; but even if it does, a focus position at such low latitudes (between Fuquene and Huancayo) would be difficult to explain. The interplanetary data are not available for this event, because the only satellite IMP 8 which was orbiting on this date, was inside the magnetosheath as per the information kindly supplied to us by Dr. N. F. Ness of NASA,

Fig. 6. Huancayo (H) versus Fuquene (H) for the event of Sep. 19, 1977. Different symbols represent different LT intervals and bracketed numbers near regression lines represent slopes.

GSFC. The lower half of Fig. 5 shows the B , θ , ϕ for the magnetosheath and the H changes at Huancayo seem to match reasonably with changes in both θ and ϕ . Thus, changes at Huancayo were probably connected with magnetospheric changes but the equatorial electrojet seems to be affected preferentially, even qualitatively. However, this needs further detailed investigation by a study of many more events.

Figure 6 shows a plot of Huancayo (H) versus Fuquene (H) for this event of Sep. 19, 1977. For the first 40 minutes (0700–0740 LT), the points (full dots) fall reasonably on a straight line. The slope is quite large (1.8) already indicating equatorial enhancement. However, for the next $1\frac{1}{2}$ hour (0750–0910 LT), the open circles show highly erratic ratios and a regression line is not even possible. Later, the crosses for 0920–1040 LT show a slope of 6.0 which reduces later to 3.0 just before noon (1050–1210 LT, crosses inside circles) but increases again to 6.0 soon after (1230–1340 LT, open squares) to reduce finally to 1.9 in the afternoon, (1400–1600 LT, full squares) same as that for the early morning (full dots). Thus, the ratio was highly erratic in the morning and fluctuated wildly near noon.

4. Summary and Conclusions

From the comparison of changes in the H component at Huancayo (equator) and Fuquene (same longitude, low latitude outside the electrojet region) during two DP2 trains, it seems that the equatorial enhancement is not proportional to the electrojet strength. In the morning hours before the electrojet peak, the ratios are abnormally high and/or very erratic. Erratic fluctuations may occur near noon also. It seems that some other parameters besides the Cowling conductivity (which is responsible for the enhanced Sq i.e. electrojet in the dip equator region) are responsible for this erratic behaviour. A possible source may be the presence of some peculiar kind of irregularities in the electrojet region, probably connected with abnormal neutral winds and wind shears. But this is only a speculation and needs further experimental investigation. It may be noted that whereas it is generally believed that SSC and SI events have an equatorial enhancement similar to the equatorial H range (electrojet) (SUGIURA, 1953; RASTOGI *et al.*, 1964), it was shown recently (KANE, 1978) that the equatorial enhancements of SSC magnitudes have also an odd behaviour. There is obviously much more happening in the equatorial electrojet region than what meets the eye.

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