IS THE MOON THE CAUSE OF EQUATORIAL COUNTER-ELECTROJET CURRENTS?

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ABSTRACT

It has been shown that the solar daily, seasonal, latitudinal and solar cycle variations of the occurrence of counter equatorial electrojet is consistent with the idea that these events are caused by the superimposition of the lunar geomagnetic field wave over the solar wave to produce the observed daily variation of the geomagnetic H field at any place. The mechanisms for the amplification of the lunar tidal oscillation on a particular day are still to be sought.

BARTELS and Johnston (1940) were the first to point out large deformations and decreases in the geomagnetic H field at Huancayo during the daytime hours of a magnetically quiet day. They suggested that on these days, the lunar daily variation is magnified so many times, of its expected value that it may even be greater than solar daily variation on the same day. Onwumechilli (1963, 1964) found the existence of such big lunar-tide days at Ibadan, even on such days on which the phase of lunar wave was completely reversed. This phenomenon of the decrease of H field during the daytime at an equatorial station, now called 'counter-electrojet' has been observed at Addis Ababa (Gouin and Mayaud, 1967), Zaria (Hutton and Oyinloye, 1970), Kodaikanal (Rastogi, 1973) and other stations near the magnetic equator (Rastogi, 1974 *a*).

Gouin and Mayaud (1967) suggested that there is no connection between the occurrence of counter-electrojet and the moon as the phenomenon has been observed at all times of the lunar day. Similar opinion was expressed by Hutton and Oyinloye (1970) even though they found that counter-electrojet occurs most frequently around 03 and 15 lunar hours. Onwumechilli and Akasofu (1972) showed that there are cases when the time of counter-*electrojets* at Huancayo *were* in complete anti-phase with the L field, and considered it as an evidence against association of all cases of S_q (H) depression with the moon. Sastri and Jayakar (1972) found that major depressions of the H field at Trivandrum occurred most frequently around lunar age 00 and 12 hr, and were practically absent around 06 and 18 hr lunar ages.

Rastogi (1973) suggested that the observed solar and lunar times of maximum occurrence of afternoon counter-electrojet events are due to the superposition of the L field on the average S field. On the same model, he predicted that the morning counter-electrojet events should be most frequent around lunar ages 06 and 18 hr. This has been confirmed later from the data of Huancayo, where the morning counter-electrojet was found to be most frequent around lunar ages 05 and 17 hr (Rastogi, 1974 *b*).

Recently, Rastogi (1974 *a*) has published the results of a detailed study of the daily, seasonal and solar cycle variations of the counter-electrojet at a number of equatorial stations. Some of the major highlights of the above study revealed that: (*i*) the counter-electrojet at equatorial stations occurs around 0700 and 1600 LT, (*ii*) the evening events are twice as frequent as the morning events, (*iii*) out of all stations studied, the events are most frequent at Kodaikanal and least frequent at Huancayo, (*iv*) the number of counter-electrojet events are inversely proportional to the solar activity, (*v*) at Huancayo, the evening counter-electrojet events are more than seven times more frequent during summer (June) than during winter (December) months. For Kodaikanal the corresponding ratio is only about 2, and (*vi*) the latitudinal extent of the counter-electrojet events is confined within ± 5° dip latitude. It is the aim of this paper to investigate whether all these points are consistent with the idea of counter-electrojet being the result of the superposition of lunar wave on the normal solar daily wave. Each of the points is discussed in turn. The basic idea is that for any solar time (T), the value of the H field would be above or below the nighttime base value depending upon whether ΔH due to average S_q field is larger or smaller than the decrease of H due to the lunar daily variation for that hour and corresponding to the lunar age of the day concerned. The relative frequency of the counter-electrojet with any geophysical parameter would be directly related to the variation of the ratio $M_2H/\Delta H$ with the above parameter.

The solar cycle and the seasonal effects in the lunar daily variation of the H field at the equatorial stations have been described for Huancayo by Rastogi (1968) and for Kodaikanal by Trivedi and Rastogi (1969). The present paper has derived the data from these publications for studying the ratio $M_2H/\Delta H$.

First we examine the lunar effect on the occurrence frequency of the counter-electrojet event. In Fig. 1 are plotted the percentage frequency of occurrence of the afternoon counter-electrojet events at number of stations in terms of the lunar age (ν) and separately in terms of the lunar time (τ). Some of the results by earlier workers are also included in the diagram. It is very clearly shown here that the occurrence of the counter-electrojet is intimately associated with the lunar age or with the lunar time. The counter-electrojet is most frequent at lunar age around 02 hr, *i.e.*, two days after new or full moon. In terms of lunar time, the counter-electrojet is most frequent at about 03 lunar hour, *i.e.*, about 3 hours after the upper or lower transit of the moon.

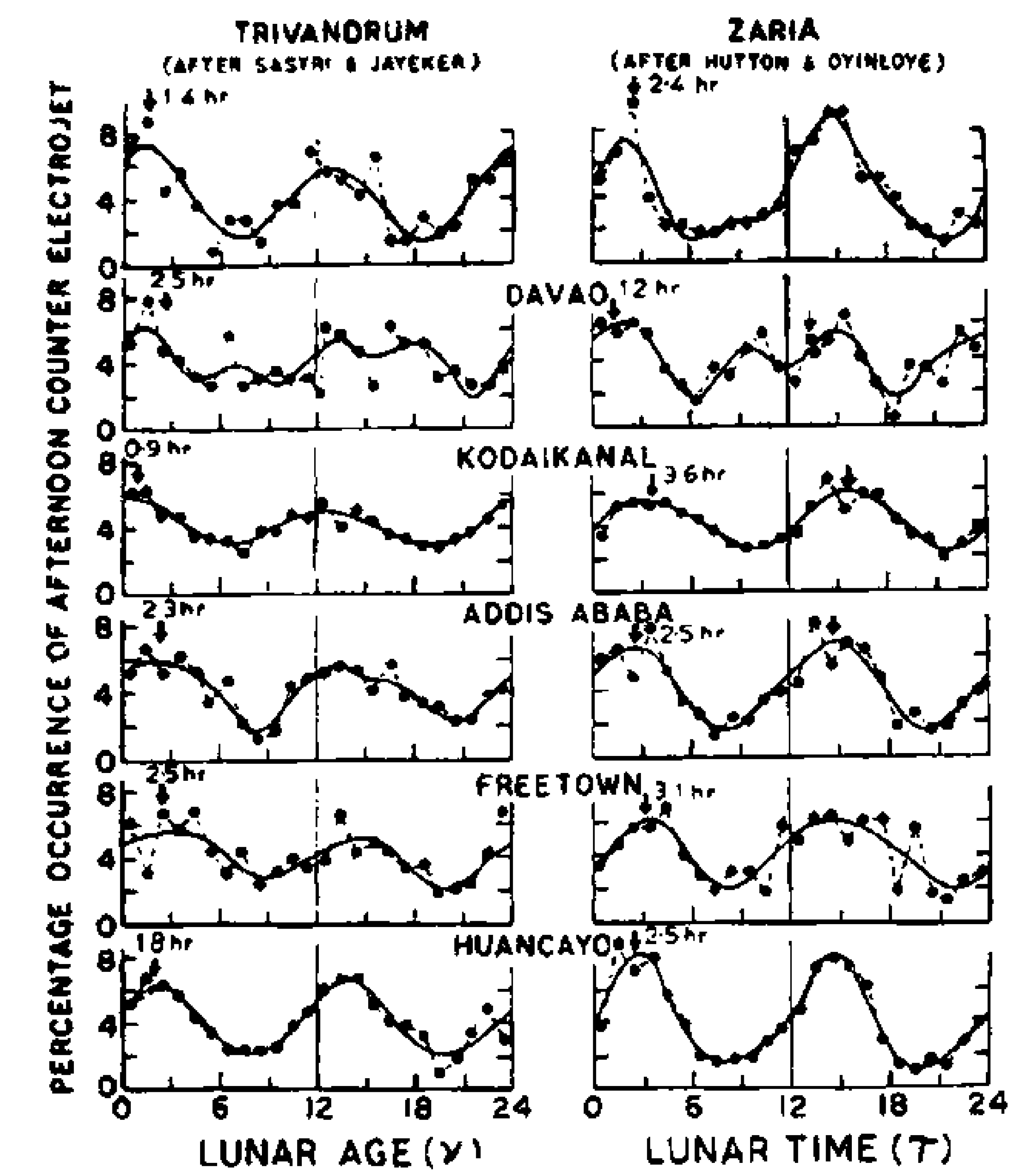

FIG. 1. The variation of the percentage occurrence frequency of the afternoon counter-electrojet events at number of equatorial stations as a function of lunar age and lunar time.

The lunar perturbations (due to semi-monthly wave) in ΔH is known to be almost absent during the night hours and is maximum around midday (Rastogi and Trivedi, 1970). The lunar daily wave, however, has largest deviation at different solar time depending on the lunar age on that day. In Fig. 2 are shown the solar daily variation of H at Huancayo averaged over all quiet days of D-months in 1951–55. The deviation of H from this average curve is also shown for days with definite lunar ages; these curves show the lunar perturbation in terms of solar time. The largest deviation is seen on lunar ages 21 and 09 hr but the minimum occurs around 1000–1100 LT when ΔH due to $S_q(H)$ is comparatively much larger and so the lunar perturbations would not have any apparent effect. On lunar ages 03 and 15 lunar hr large (about 10 γ) depression occurs around 1,600 LT when ΔH due to S_q variation is less than 10 γ, and thus one may expect a negative value of ΔH on those days due to combined effects of the moon and the sun. Thus the counter-electrojets in the evening hours are expected to be on days with lunar age around 03 or 15 hr. Similarly at the morning hours, large deviation in lunar wave comparable to $S_q H$ at the same time, is expected on lunar ages around 18 and 06 hr. A more detailed picture can be obtained by studying the variation of the ratio $(M_2/\Delta)H$ as a function of solar time. In Fig. 3, it is seen that although the maximum aplitude of lunar $M_2(H)$ is about ten times smaller than the solar ΔH, during the midday hours, the ratio $(M_2/\Delta H)$ has two maxima in the morning and in the afternoon hours. The ratio is only about 0·1–0·2 during

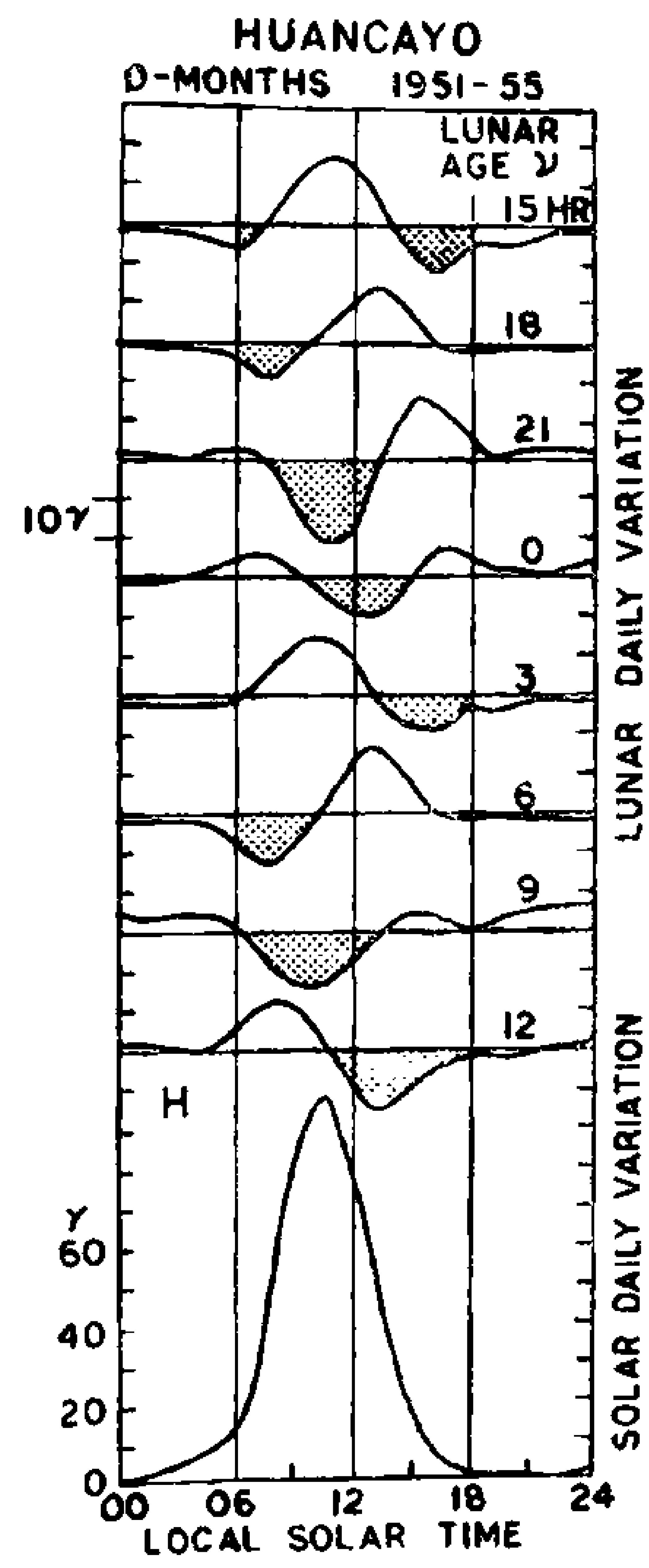

FIG. 2. Average solar daily variation of ΔH at Huancayo for D-months compared with the cooresponding lunar daily variations on days of definite lunar ages.

midday but is about 0·3–0·8 during 0700 LT or 1600–1700 LT. These two times are approximately the times when the counter-electrojets are most frequent.

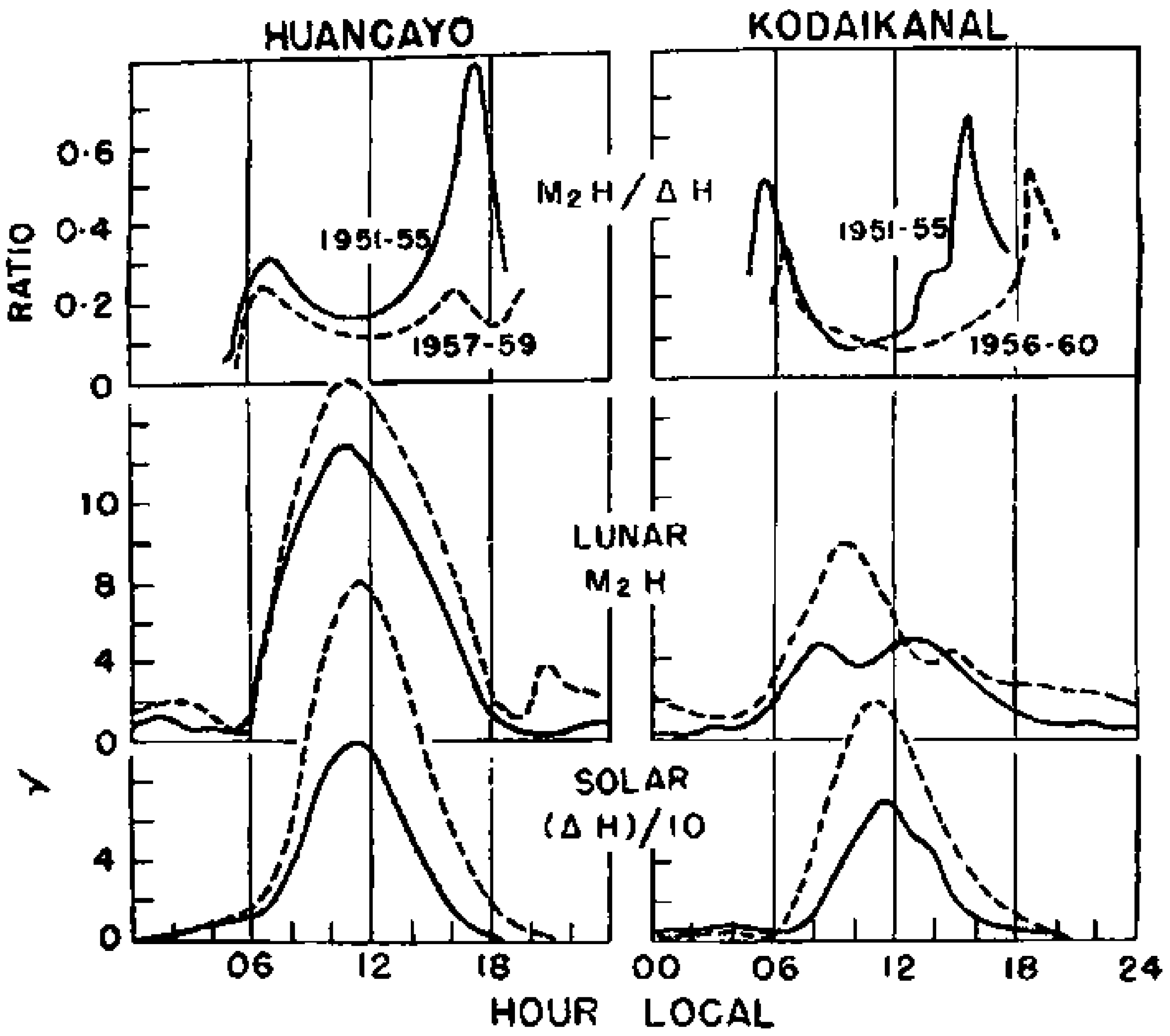

FIG. 3. The variation with the time of the day of the change of H field (ΔH), lunar semi-monthly tide in H (M_2H) and the ratio $M_2H/\Delta H$ for equatorial stations Huancayo and Kodaikanal for the year of low and high solar activity.

It is seen that on the average the ratio ($M_2H/\Delta H$) is larger in the evening than in the morning hours suggesting greater probability of counter-electrojet in the evening than in the morning, which is consistent with the observed facts.

Examining the curves for the years of low and high solar activity, one finds that both M_2H as well as ΔH are larger during years of high solar activity but the ratio $M_2H/\Delta H$ is much smaller in the high than in the low sunspot years. This would suggest that the counter-electrojets should be less frequent during years of high sunspot number, which is again consistent with the observations.

It was also shown by Rastogi (1974 *a*) that the number of afternoon counter-electrojet events at Huancayo is about 7 times more frequent in summer (D-months) than in winter (J-months); at Kodaikanal, the ratio is about 2 while at other stations the occurrence is practically independent of season. In Fig. 4 are shown the ratio $M_2H/\Delta H$ at Huancayo and Kodaikanal as a function of local time for different seasons. It is seen that at Kodaikanal, the ratio is practically independent of season, but at Huancayo the maximum value of the ratio is about 1·8 in D-months and only 0·3 in J-months. Thus the counter-electrojet events at Huancayo should be most frequent during D-months while at Kodaikanal seasonal variation ought to be very feable, which is again consistent with the observed fact.

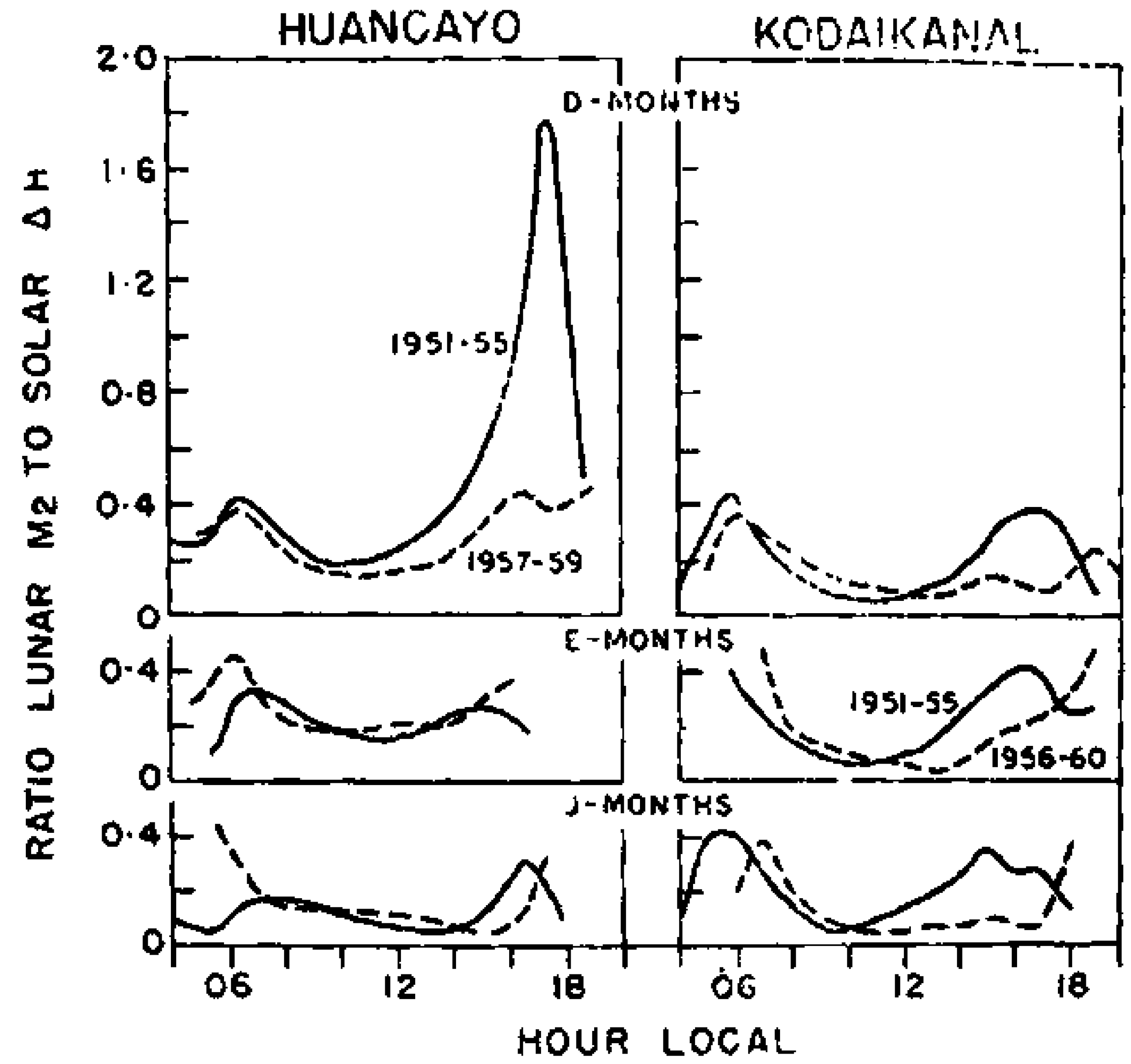

FIG. 4. The solar daily variation of the ratio of the amplitude of lunar semi-monthly tide in H (M_2H) to the change in H from the mean nighttime level at each season of low and high sunspot years for Huancayo and Kodaikanal.

The diurnal, as well as seasonal variations of the occurrence of the counter-electrojet events at low-latitudes is consistent with the idea that the observed value of the H field is a combined effect of the solar variation and the lunar wave. There may be, of course, large deviations in this idea for individual cases of the counter-electrojet events.

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