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# Variability of the $S_q$ focus position in the South American continent

R P KANE

Instituto de Pesquisas Espaciais-INPE C. P. 515, 12201 São José dos Campos, SP, Brasil

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**Abstract.** The daily variation of the H component at Pilar (31·7°S, 63·9°W) and Trelew (43·3°S, 65·3°W) in the South American continent indicates a great variability in amplitude from season to season and even from day to day. However, Pilar always remains equatorward of the southern $S_q$ focus. On the other hand, Trelew is in most cases slightly poleward of the $S_q$ focus; but the focus has large latitudinal excursions above and near Trelew. A cause of this variability could be the encroachment of polar ionospheric current systems into the low latitude ionospheric $S_q$ current system.

**Keywords.** $S_q$ focus; South America; H component.

## 1. Introduction

In the absence of storms and substorms, the H component of geomagnetic field shows a daily variation. For night-time (6 p.m. to 6 a.m.), the variation is almost nil. During daytime, for stations located within 30° of the equator, H increases from 6 a.m. to about noon and later, decreases up to 6 p.m. For stations near 30°N or 30°S, the daily variation is almost nil. For stations between 30° and the poles, the daily variation is *reversed* viz a noon *minimum*. Figure 1, based on Forbush and Casaverde (1961) and Price and Stone (1964), illustrates the H, D, Z variations for the American longitudes for equinoxes in 1958 (see also Kane 1976). Such a pattern can be explained by assuming the presence of a current system in the ionospheric *E* region. Matsushita (1969) illustrated the external $S_q$ (Solar quiet-day variation) current system consisting of two $S_q$ current vortices, one in each hemisphere (north and south), with $S_q$ foci roughly at 30° geomagnetic latitudes. For stations located under the focus i.e. at $\sim 30°$ latitudes (north or south), the H variations would be almost zero, as currents on northward and southward side are opposite to each other and hence, their magnetic effects would cancel each other. The strength of the current systems as also the focus positions are known to change appreciably with season as also from day to day (Chapman and Bartels 1940; Vestine *et al* 1947; Hasegawa 1960). Studies at different longitude zones show that the unusually high or low position in one zone need not necessarily have a corresponding high or low in other longitude zones (Matsushita 1960). From the 1958 data for the American, European and Australian zones, Gupta (1973) reported that the two foci (north and south) move as a *rigid* system, the largest movement occurring in the American sector. Tarpley (1973) reported that in each equinox, one focus or the other was nearer to the equator. It should be noted, however, that the distribution of magnetic observatories on the globe is very uneven, with large concentrations in Europe and America and very few stations in the southern

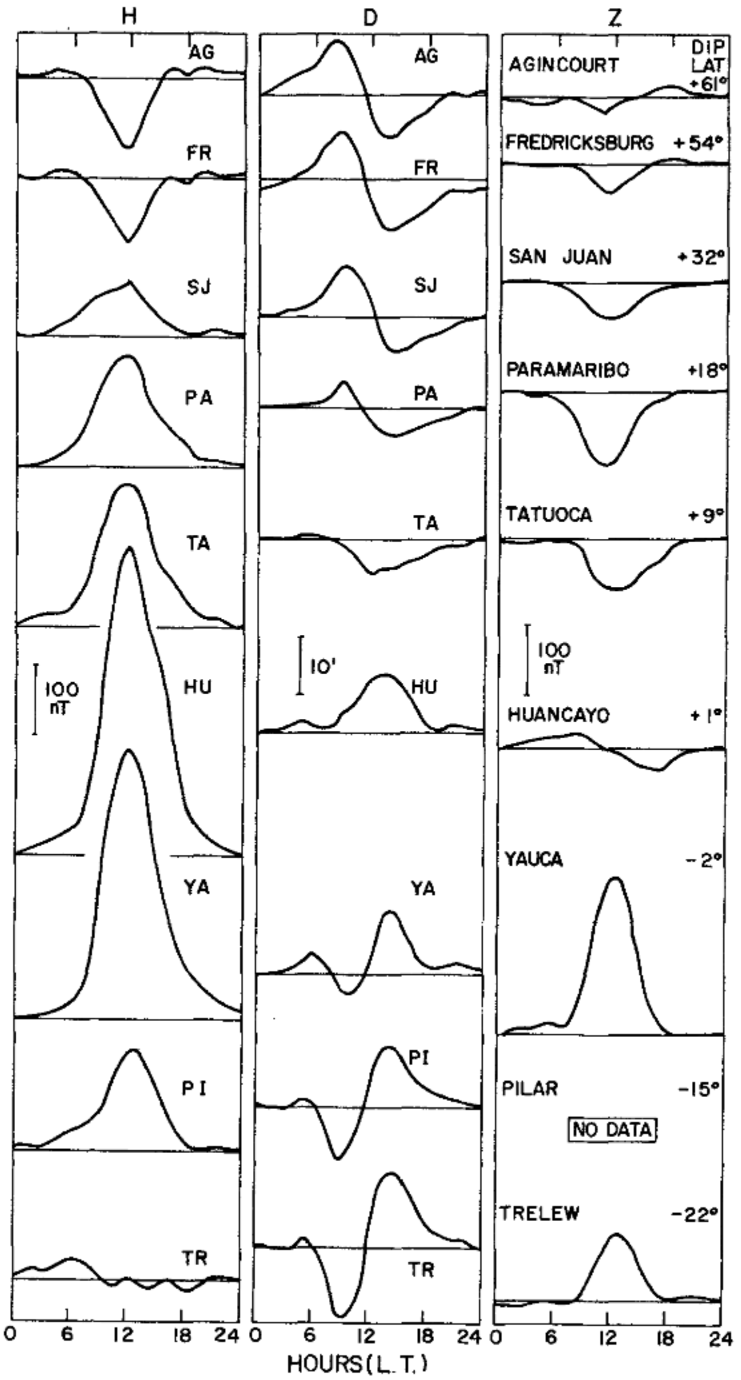


**Figure 1.** Average daily variation of H, D, Z, at various locations in the American longitudes for equinoxes in 1958 (based on Forbush and Casaverde 1961 and Price and Stone 1964).

hemisphere and almost none in the vast regions occupied by sea. In the South-American continent, the only stations near the $S_q$ focus are Pilar (31·7°S, 63·9°W) and Trelew (43·3°S, 65·3°W), both in Argentina. The bottom part of figure 1 shows the average patterns seen at Pilar and Trelew. As can be seen, the H pattern at Pilar is that of a location between $S_q$ focus (in this case, southern $S_q$ focus) and geomagnetic equator. At Trelew, H variation is almost zero, indicating that Trelew is almost under the $S_q$ focus. It may be noted that geographically, Trelew is almost south of pilar by $\sim 12°$. Also, in this region, the geomagnetic equator is located south of the geographic equator, with a considerable tilt. As a result, the geomagnetic latitude of pilar is –20·2° and that of Trelew is –31·7°, thus leaving Trelew very near the southern $S_q$ focus. In this communication, the H variations at these two locations are studied and their variability illustrated.

## 2. Data

For the present analysis, data for the H component for the 5 *International Quiet Days* in each month of 1958 for Pilar and Trelew are used. The monthly averages refer to the average of the 5 quiet days only. Seasonal and yearly averages are obtained from the monthly averages.

## 3. Results

Figure 2 shows the average H variation at Pilar (dashes and crosses) and at Trelew (full lines). As can be seen from figure 2(a) for the yearly average curves, Pilar shows a noon-time maximum indicating that it is located equatorward of the $S_q$ focus. On the other hand, Trelew shows a mixed pattern. In the early morning and late afternoon hours, it shows variations similar to Pilar; but from about 0800 to 1400 hours, the pattern is reversed at Trelew, indicating that Trelew is beyond the $S_q$ focus, towards the South Pole. Similar patterns are seen for the equinox months (March, April, September, October) in figure 2(b), which, incidently, is the same as the lower part of the first column of figure 1. For the (southern) summer months (January, February, November, December), figure 2(c) shows an asymmetric behaviour for Trelew, the maximum reversal occurring earlier than noon. For (southern) winter (May, June, July, August), figure 2(d) shows that the maximum reversal for Trelew occurrs at noon. For Pilar, the maximum amplitude is for the summer months, as expected. Thus, on the average, Pilar is always between the $S_q$ focus and equator while Trelew is slightly beyond the $S_q$ focus (towards S. pole).

Figure 3 shows the monthly average plots. The five dates corresponding to the five International Quiet Days in each month are indicated and the plots are the average of these five days only. For Pilar, the maximum amplitude is in January (peak of local summer) reducing to low values by June–July (winter) and increasing again up to December; but the maximum is near noon for all months indicating that Pilar is always equatorward of the $S_q$ focus. For Trelew, the daily variation patterns change sometimes abruptly (e.g. from September to October). In July and August, the daily variation at Trelew is negligible throughout the day, indicating that Trelew is *right under* the $S_q$ focus in these months. In other months, there is a tendency for daytime

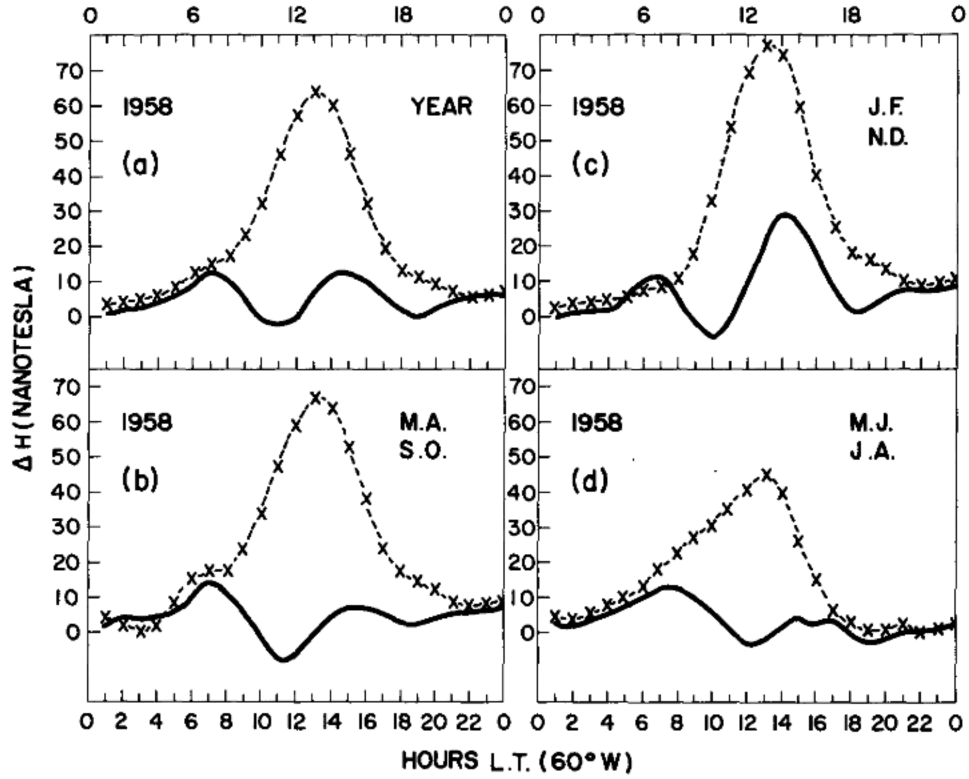


**Figure 2.** Average daily variation of the H component at Pilar (dashes and crosses) and at Trelew (full lines) for (**a**) the yearly average, (**b**) Equinoxes, (**c**) Summer and (**d**) Winter of 1958.

minimum, indicating that Trelew is beyond the $S_q$ focus, towards the S. Pole.

How do the patterns vary from day to day? Figure 4 shows a plot for three *consecutive* International Quiet days in January, February, April, May, August and October. In all cases, the pattern for Pilar is a near noon maximum. The amplitudes vary considerably from day to day (up to 20%); but Pilar is always equatorward of the $S_q$ focus. For Trelew, the patterns can change *radically, from one quiet day to the next*. Thus, the $S_q$ focus has large day-to-day latitudinal variations near and around the location of Trelew. The average monthly, seasonal and yearly patterns are, therefore, averages of *heterogeneous* quantities.

## 4. Discussion and Conclusion

The H variations at Pilar and Trelew indicate that whereas the amplitude at Pilar may change by as much as 20% from day to day, Pilar is always located equatorward of the $S_q$ focus. On the other hand, the $S_q$ focus may oscillate over Trelew by several degrees in latitude, even on a day-to-day basis. On a seasonal basis too, the changes can be large (about 15°, as estimated by Tarpley 1973). Kane (1974) showed that, on the average, when the $S_q$ current strength was larger, the $S_q$ focus shifted equatorward.

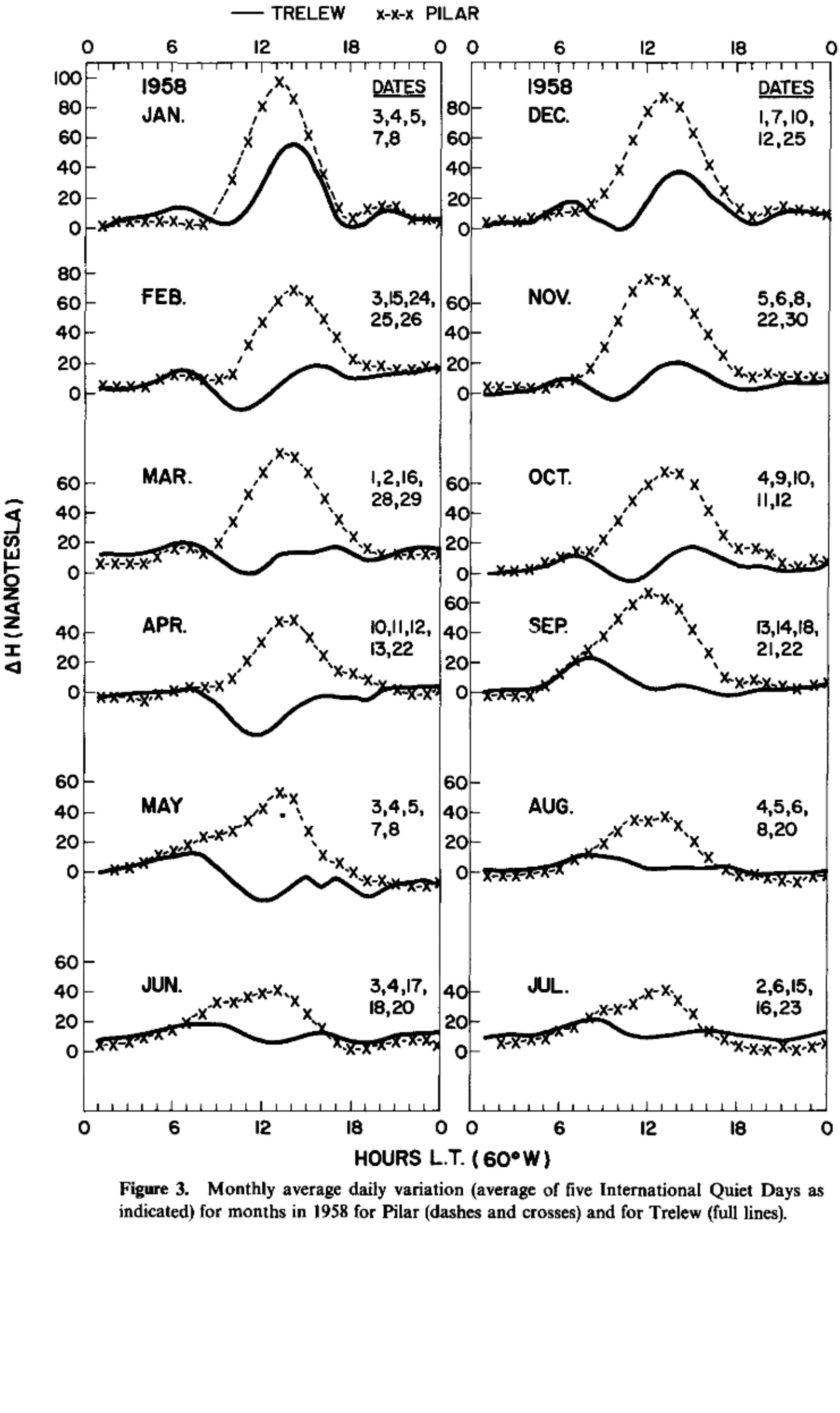


**Figure 3.** Monthly average daily variation (average of five International Quiet Days as indicated) for months in 1958 for Pilar (dashes and crosses) and for Trelew (full lines).

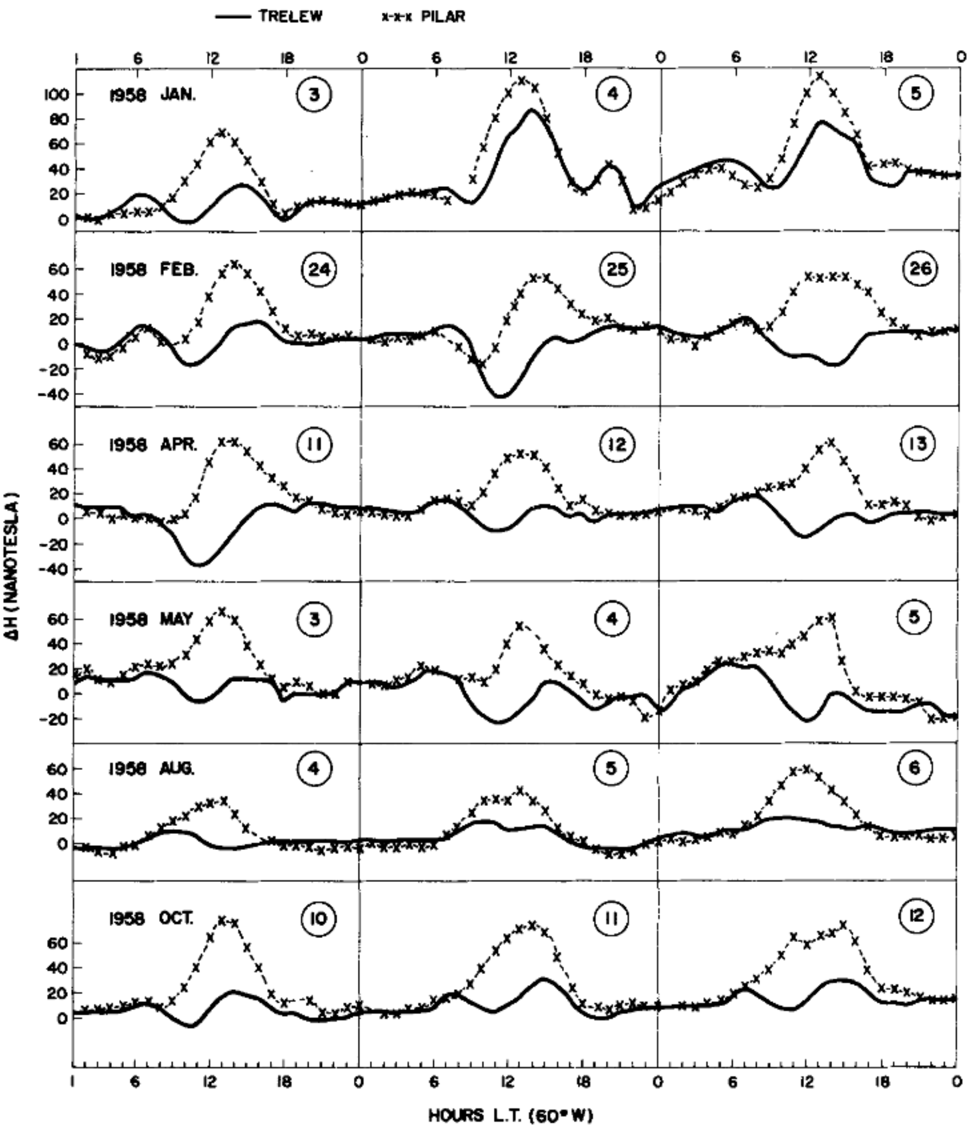


**Figure 4.** H plots at Pilar (dashes and crosses) and Trelew (full lines) for three consecutive International Quiet Days (dates indicated) in various months of 1958.

There can be several reasons for the changes in the $S_q$ focus position. The average patterns of daily variations of H, D, Z are illustrated in figure 1. As can be seen, H variations are symmetric about the geomagnetic equator with similar effects at given latitudes, irrespective of whether it is north or south. But the D variations in the northern hemisphere and the southern hemisphere are *opposite* to each other. From a study of the D variations, Hutton (1967a, b) indicated the possibility of the northern hemisphere $S_q$ current system encroaching into the southern hemisphere, or vice versa. Hasegawa (1960) pointed out that these changes are related more to the changing ionospheric wind patterns rather than the changing ionospheric conductivities. Here, the meridional circulation may play a crucial role, specially during summer and winter seasons when transequatorial winds carry plasma from the summer to the winter hemisphere. Also, the ionospheric currents would have a three-dimensional structure in which meridional currents would flow towards the equator (Untiedt 1967; Sugiura and Poros 1969) or away from the equator (Takeda and Maeda 1980, 1981). Evidence of such a meridional current system from MAGSAT data is reported by Maeda *et al* (1982). Changes in the Interplanetary Magnetic Field (IMF) are known to cause considerable variations in the polar region. There is good reason to believe that these changes extend to lower latitudes too (Matsushita 1977). As pointed out by Mayaud (1967), there may be two current systems, one the $C_M$ system causing the $S_q$ foci at middle latitudes and another the $C_p$ system having centres in the polar regions. Thus, the variability of $S_q$ focus position may also be a result of a variable encroachment of the $C_p$ system into the $C_M$ system. As such, a comparison of geomagnetic data in the Antarctic region with data at low latitudes (Trelew, Pilar, Vassouras etc.) would be of great interest. It is hoped that such a comparison would be possible in the near future with the installation and operation of a Brazilian (INPE) magnetometer at the Antarctic location of Comandante Ferraz. In this connection, it is of great interest to note that Brown and Williams (1969) noted Abnormal Quiet days (AQD) in middle latitudes when the diurnal variation changes occurred *outside* the interval 0830–1330 hours indicating great distortions (even on magnetically quiet days), probably due to encroachment of polar currents.

The present analysis deals with data for the high sunspot year 1958. A similar study for low sunspot years would be useful and would be conducted as and when data are available to us.

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