Behaviour of the quiet day geomagnetic variation at Livingston Island and variability of the Sq focus position in the South American-Antarctic Peninsula region

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The characteristics of the regular daily variation at the relatively new geomagnetic observatory of Livingston Island have been studied. They include the seasonal and solar cycle variabilities. Studies of the solar cycle variability have been carried out thanks to the fact that there are presently more than eleven years of definitive data already available. The seasonal behaviour of the quiet-time daily field variations are those expected from earlier studies for a mid-latitude observatory placed at the south of the southern hemisphere current focus. There is also a clear dependence of the Sq amplitude on solar activity, though the Sq amplitude maximum occurs about two years later than the sunspot maximum. A contemporaneous analysis for solar cycle 23 has been carried out for observatories located in the same longitudinal sector, with the aim of identifying the latitudinal displacements of the current focus that affect the observed Sq variations. The uncertainties associated with the method employed for determining the focus positions are due to the scarcity of observatory data in the South American-Antarctic Peninsula region, but it can still be asserted with a certain reliability that focus latitudes are higher during summer and equinoxes than in winter. On the other hand, it is difficult to establish a correlation between focus latitude and Solar Sunspot Numbers.

1. Data

The Livingston Island Observatory (LIV), which is operated by the Ebro Observatory Institute (Spain), was deployed in December 1996 in the vicinity of the Spanish Antarctic Station, located in the South Shetland Islands, to the North of the Antarctic Peninsula. The data used for this study were the hourly mean values (HMVs) of the H, D and Z. Values from Vassouras (VSS), Trelew (TRW), Port Stanley (PST), and Argentine Islands (AIA) were added for the anlaysis of the Sq focus behaviour. The values for the Sq variations were obtained by subtracting from the HMVs, a trend determined by the two local midnight levels on each side of the quiet day. The study was carried out on a monthly basis, based on monthly averages using the five International Quiet Days of each month.

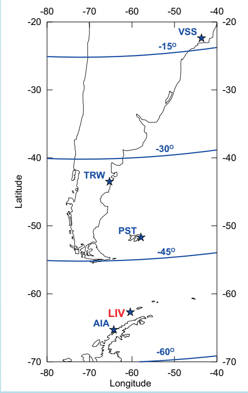

Fig. 1. Map showing the locations of the observatories. Geomagnetic latitudes -15º, -30º, -45º, and -60º are shown.

2. Variations at LIV

The amplitudes of the daily magnetic variation are largest around the summer solstice and progressively fade through the equinoxes to the winter solstice. During active years the Sq amplitudes are about twice as large as during quiet years. It is usually assumed that the amplitude of the ionospheric field variations, with its associated induced field variations, varies linearly with the solar activity. To verify if this is the case for LIV, the correlation between the 1-year running averaged D ranges and the corresponding smoothed monthly SSN was studied. As in Torta et al. (2009), this element was chosen because H and Z ranges could be more affected by latitudinal displacements of the Sq focus. There is some hysteresis between both signals and a change to a lower slope between moderate and high activity in both phases of the cycle.

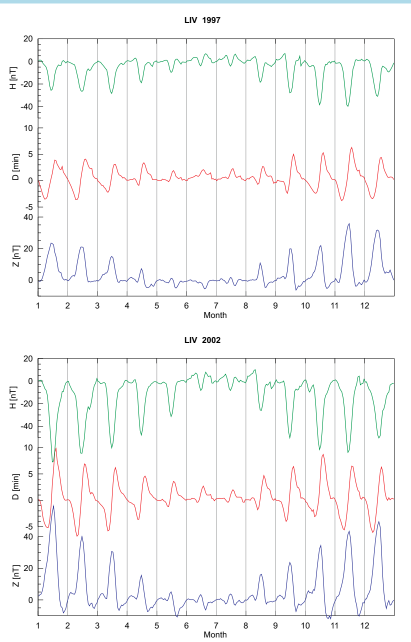

Fig. 2. Daily LT variations at LIV. Top: for a low activity year. Botom: for a high activity year. They were obtained from hourly mean values averaged over the five quietest days of each month.

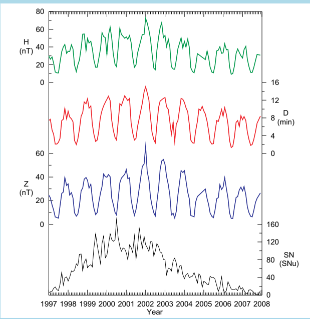

Fig. 3. Time evolution of the daily amplitude of the Sq variation at LIV and of the monthly averaged SSN.

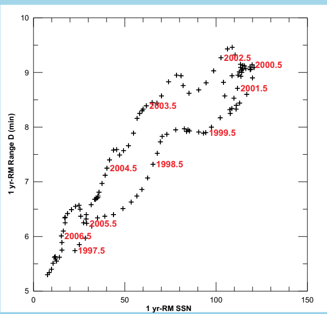

Fig. 4. 1-year running mean of the monthly means of the daily range of D at LIV vs. the corresponding values of the SSN. Labels every 12 months indicate the sense of time evolution.

3. Variability of the Sq focus position

The variability of the Sq focus position was estimated with the method suggested by Stening et al. (2007). This consists, firstly, of determining the time when the variation of D passes through zero at each observatory. The variation of H evaluated at that time is then plotted against latitude, and the focus position is obtained from a least squares fit; namely, that latitude at which this line crosses zero. The analysis was developed on a seasonal basis (taking the variations of H and D from all the available international quiet days for each Lloyd's season of each year).

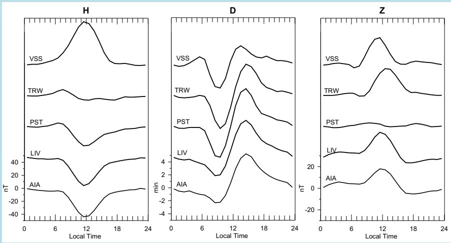

Fig. 5. An example of the average daily variations at the different observatories: year 1999, equinoctial season.

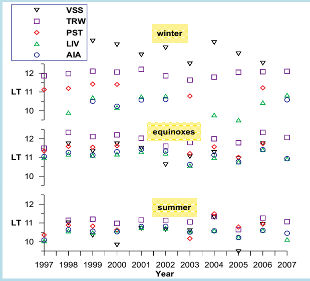

Fig. 6. Time at which the variation of D passes through zero for each season and year at each observatory.

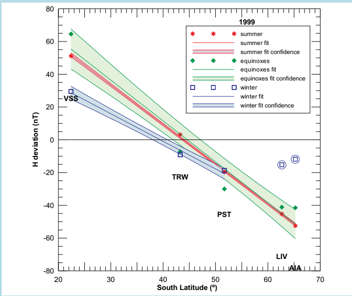

Fig. 7. Plot of variation of H versus observatory latitude used for the determination of the focus latitude of the ionospheric current system by least squares fits for each season of 1999. The standard uncertainties of the fits are also displayed as grey shadings. Symbols for AIA and LIV for winter are encircled to indicate that they were not considered for the fit.

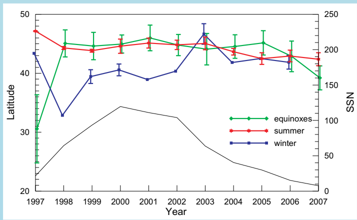

Fig. 8. Evolution of the determined focus latitude of the ionospheric current system for each year and season of solar cycle 23 (with their error bars), along with the yearly averaged Solar Sunspot Number.

4. Discussion

The major characteristics of the quiet-time daily field variations and their associated current functions found in this study for LIV are those expected from earlier studies. There is also a clear solar activity dependence of the Sq amplitude, which is mainly explained by the effect of the ionospheric conductivity. The time lag between both signals could be related to that observed globally between SSN and geomagnetic activity. On the other hand, the ellipse of fig. 4 is not perfect, with a change towards a lower slope being appreciated at around SSN=70. This does not agree with the result of Olsen (1993), who found a completely linear dependence between the strength of the Sq and the SSN.

Our analysis confirms that TRW is in general very close to the southern Sq focus, although some movements do exist which depend on the season and the solar activity level. Focus latitudes are higher during the summer and equinoxes than in winter. A correlation between focus latitude and SSN is difficult to establish due to the lack of sufficient data for such a robust determination, and because in years of solar maximum many of the 5 IQDs for each month contain some disturbed intervals that prevent a precise determination. The time of appearance of the focus was found closest to noon during the equinoxes. In winter, these times are erratic, probably due to the superposition of field-aligned currents resulting from interhemispherical asymmetries.

References

Olsen, N., The solar cycle variability of lunar and solar daily geomagnetic variations. *Annales Geophysicae*, **11**, 254-262, 1993.

Stening, R. J., T. Reztsova, L. H. Minh, Variation of Sq focus latitudes in the Australian/Pacific region during a quiet sun year, *J. Atmos. and Solar-Terr. Phys.*, **69**, 734740, 2007.

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