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Solar-Terrestrial relationships at solar cycle minimum

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Abstract. In this paper we present the results of the analysis of geomagnetic field measurements conducted from May 31 to June 14, 2007, around the summer solstice during the current solar activity minimum phase. Such campaign of measurements was conducted in the framework of the Italian initiatives for the International Heliophysical Year. During the whole period, the geomagnetic field does not show any development of storms due to the absence of a persistent interplanetary magnetic field southward component. We focused our attention on the moderate geomagnetic pulsation activity in the Pc5 (1.6-6.6 mHz) and Pc3 (22-100 mHz) frequency range. Pc5 pulsations were mainly observed in correspondence to the solar wind pressure variations which characterize the interaction regions between the corotating streams occurring in the period. The analysis suggests a solar wind driving of pulsations. On the other hand, the observed Pc3 pulsations seem to be related to the penetration in the magnetosphere of upstream waves.

Key words. Sun – Solar wind – Earth's magnetosphere – MHD waves

1. Introduction

In the framework of the initiatives for the International Heliophysical Year, the Italian solar-terrestrial community proposed the use of different and complementary ground based instruments managed by the community itself together with spacecraft data to monitor the solar-terrestrial environment during the current solar activity minimum phase (IHY/CIP57, coordinated by M. Storini). Two campaigns of measurements were planned in 2007 around the solstices, when the Earth is at zero heliographic latitude: May 31-June 14 and December, 1-15. We contributed to these campaigns by conducting geomagnetic field measurements at several low latitude stations forming the SEGMA array. SEGMA (South European GeoMagnetic Array, cooperation between the University of L'Aquila and the Space Research Institute of Graz, Austria) is a low latitude meridional magnetometer array which consists of three stations in Italy (L'Aquila, Ranchio, Castello Tesino) and one in Hungary (Nagycenk). In this paper we show the results of the analysis of the measurements obtained at L'Aquila station during the first campaign May 31-June 14, 2007, focusing our attention on ULF pulsation activity.

ULF geomagnetic pulsations are low frequency ($f <$ plasma frequency or ion-cyclotron frequency) magnetic field fluctuations with periods ranging from seconds to minutes and

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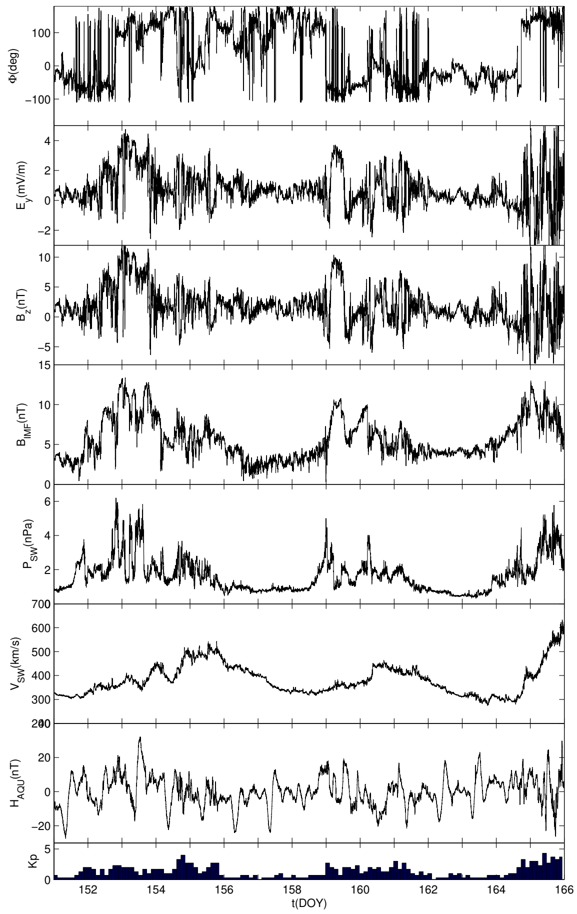

Fig. 1. WIND measurements and ground observations for 31 May-14 June 2007. From the bottom are shown the Kp index, the geomagnetic field horizontal component H at L'Aquila, the SW speed, the SW dynamic pressure, the IMF strength, the IMF north-south component, the Ey component of the SW electric field and the IMF orientation in the ecliptic plane.

are divided in continuous, quasi sinusoidal pulsations and irregular pulsations. They are further divided in subgroups on the basis of their periods, the continuous starting with Pc1 (0.2-5 Hz) and ending with Pc5 (1.6-6.6 mHz). We are mostly interested in the low and mid frequency range corresponding to Pc5 and Pc3 (22-100 mHz) pulsations. They originate from the interaction of the magnetosphere with the solar wind (SW) through different mechanisms. The main source for Pc3 pulsations can be identified in the upstream waves; these waves are generated (through ion-cyclotron instability) by protons reflected off the bow shock along the interplanetary magnetic field (IMF) lines (as a consequence, for the typical spiral IMF orientation they are observed mainly in the morning side); they have a frequency linearly dependent on the strength of the IMF, i.e. f (mHz) = $6B$ (nT), (Troitskaia & Bol'Shakova 1988); moreover, their occurrence is associated to low values of the cone angle (i.e. the angle between the Sun-Earth direction and the IMF) indicating a direct transmission through the subsolar bow shock (Russell et al. 1983). The Kelvin-

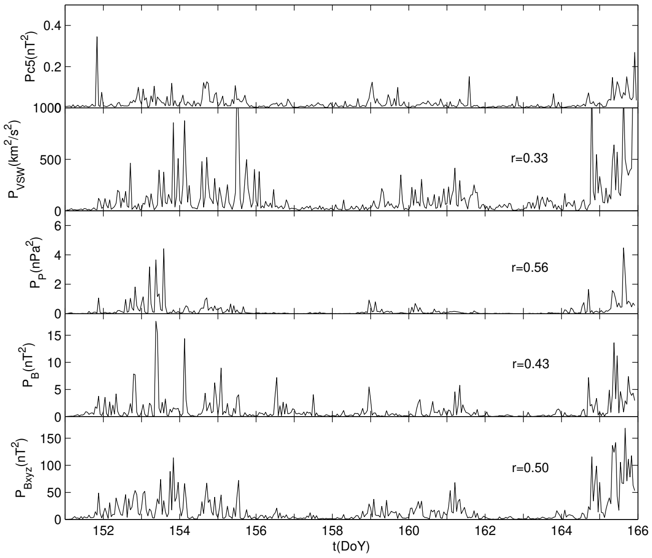

Fig. 2. From the top are shown the integrated hourly power of Pc5 pulsations, the integrated power in the same frequency range of the SW speed fluctuations, the SW dynamic pressure, the IMF magnitude. In the bottom panel we also show the total integrated power of the fluctuations in the IMF components.

Helmoltz instability on the magnetopause is the main source for the low frequency pulsations (Pc5). Since the waves are due to the SW flow on the magnetopause flanks, the propagation direction is antisunward away from local noon, westward in the morning and eastward in the afternoon. SW discontinuities, such as shock waves, impacting on the magnetopause are a further Pc5 pulsation source in that they may generate magnetospheric cavity/waveguide modes (Kivelson & Southwood 1985; Samson et al. 1992). More recent results have shown that geomagnetic and magnetospheric fluctuations can be directly driven by SW compressional fluctuations at the same frequencies (Kepko et al. 2002; Villante et al. 2007).

2. Experimental results

The geomagnetic field measurements come from L'Aquila station (36° CGM latitude). For a comparison with the interplanetary medium conditions, we considered the SW and IMF parameters from WIND which moves from 248 to 262 Earth radii in the radial direction during the period of interest.

Figure 1 shows the interplanetary parameters and ground observations at L'Aquila during the campaign. It can be observed the occurrence of three SW streams at intervals of about 6 days: the speed changes from less than 350 km/s to more than 500, 400 and 600 km/s, respectively. The interface regions between the slow and fast SW are characterized by several variations in the dynamic pressure (reflecting density variations), high IMF values and the change of the IMF orientation in the ecliptic plane.

The geomagnetic field H component is characterized by the diurnal variation. It does not show any development of storms during the whole time period, since the Bz component reaches only small negative values and for very short time intervals. During such intervals, the eastward (negative) electric field (proportional to the magnetospheric convection electric field) is weak, with values lower than 2 mV/m. The moderate geomagnetic ac-

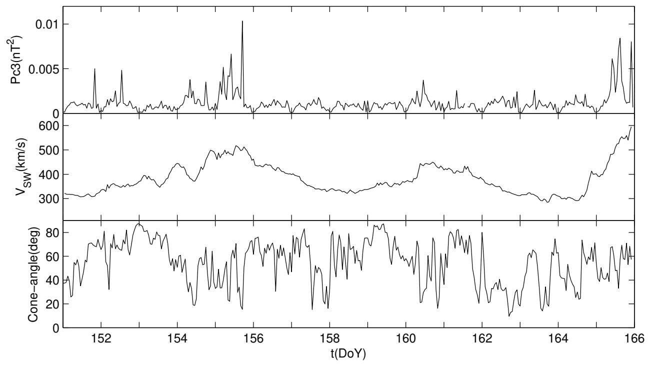

Fig. 3. From the top are shown the integrated hourly power of Pc3 pulsations, the SW speed and the cone angle.

tivity is confirmed by the Kp index which is always lower than 5. During the examined period we observe a low geomagnetic pulsation activity, detectable mainly in correspondence to SW pressure variations. From Fig. 2 it can be seen that higher values of the Pc5 fluctuation power are observed in correspondence to higher values of the SW/IMF fluctuations. We computed the correlation coefficients for the logarithm of the hourly powers (the SW and IMF data are time shifted of 1 hr, roughly the propagation time from Wind). The best correlation (r = 0.56) is observed with the SW dynamic pressure fluctuations. This result is consistent with a solar wind driving of magnetic pulsations.

In Fig. 3 we show the integrated hourly power in the frequency range 22-100 mHz (Pc3 pulsations), the hourly values of SW speed and cone angle. The power of Pc3 pulsations show a diurnal modulation with lower values around midnight. If upstream waves were the source for these pulsations there should be a dependence on the SW speed and cone angle values. Indeed, we can observe that the average level of pulsations increases when the SW speed is high and the cone angle is lower than 45°, although the cone angle seems to have a minor role (see, for example, on day 165). These features are consistent with the interpretation of Pc3 pulsations in terms of penetration in the magnetosphere of upstream waves.

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References

Kepko, L., Spence, H. E., & Singer, H. J. 2002, Geophys. Res. Lett., 29, 080000

Kivelson, M. G. & Southwood, D. J. 1985, Geophys. Res. Lett., 12, 49

Russell, C. T., Luhmann, J. G., Odera, T. J., & Stuart, W. F. 1983, Geophys. Res. Lett., 10, 663

Samson, J. C., Harrold, B. G., Ruohoniemi, J. M., Greenwald, R. A., & Walker, A. D. M. 1992, Geophys. Res. Lett., 19, 441

Troitskaia, V. A. & Bol'Shakova, O. V. 1988, Advances in Space Research, 8, 413

Villante, U., Francia, P., Vellante, M., et al. 2007, Journal of Geophysical Research (Space Physics), 112, 8202