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Dependence of geomagnetic field line resonant frequencies on solar irradiance

M. Vellante[1] and M. Förster[2]

[1] Dipartimento di Fisica, Universita dell'Aquila, Via Vetoio, 67010 Coppito L'Aquila, Italy
e-mail: massimo.vellante@aquila.infn.it
[2] Max Planck Institute für extraterrestrische Physik, Garching, Germany

Abstract. By performing a cross-phase analysis of ULF wave magnetic measurements recorded at the South European Geomagnetic Array (SEGMA) we have investigated the temporal variation of the resonance frequency (f_R) of a low-latitude geomagnetic field line ($L = 1.61$) during a 3-year period from 2002 to 2004. We find that f_R is clearly anticorrelated with the 10.7 cm solar radio flux $F_{10.7}$. This result indicates that a variation of the ionization rate in the ionosphere, induced by a variation of the solar EUV/X-ray radiation, influences the whole distribution of the plasma along low-latitude field lines.

1. Introduction

There is a vast experimental evidence, from space (Takahashi et al. 2004) and ground-based (Menk et al. 1999) measurements, that the geomagnetic field lines very often resonate forming standing magnetohydrodinamic waves between conjugate ionospheres. This is known in the literature as the field line resonance (FLR) phenomenon (Southwood 1974). The frequency of these oscillations (f_R) depends on the field line length, the magnetic field strength and the plasma mass density ρ along the field line. As a rule of thumb, for a given field line, an increase of the field aligned plasma density corresponds to a decrease of the oscillation frequency ($f_R \propto \rho^{-1/2}$).

FLR frequencies can be accurately determined by means of a cross-phase analysis of ground-based ULF wave measurements recorded at stations closely spaced in latitude (Waters et al. 1991). This allows to monitor, almost routinely, temporal variations of the magnetospheric density.

The Physics Department of the University of L'Aquila in cooperation with the Space Research Institute of Graz has established in south Europe a magnetometer array (SEGMA, South European GeoMagnetic Array) for ULF wave measurements (Vellante et al. 2002). It is composed by four stations latitudinally equispaced between 36 and 43 degrees (corrected geomagnetic coordinates). This spatial configuration is particularly suitable for detecting FLR signatures, allowing to monitor the dynamics of the inner magnetosphere. We report here the results of an analysis of the temporal variation of the daily averages of f_R at $L = 1.61$ over the period 2002-2004.

2. Experimental results

By applying the cross-phase technique (Waters et al. 1991) we computed the daily averages of the FLR frequency f_R at $L = 1.61$ over a 3-

year period from 2002 to 2004. We find that f_R shows a clear 27 days modulation and is clearly anticorrelated with the daily values of the 10.7 cm solar radio flux $F_{10.7}$ which is commonly considered as a proxy for the UV irradiance variation. The two quantities are related by the following linear best fit: f_R(mHz)= $95 - 0.21F_{10.7}$, with a correlation coefficient of 0.75. This result is interpreted in the following way: an increase of the solar EUV/X-ray radiation increases the ionization rate in the ionosphere; the produced ions diffuse along the local field line increasing the field aligned mass density; as a consequence the natural frequency of oscillation of the field line decreases. We find indeed that the rate of variation of f_R (0.21 mHz per solar flux unit) is in reasonable agreement with the theoretical value (0.27) predicted by a ionosphere-plasmasphere model (Förster and Jakowski 1988). We also performed an analysis for different time lags and found that the maximum correlation between $F_{10.7}$ and f_R is obtained for a time lag of 1-2 days. Similar delays have been already found in atmospheric and ionospheric parameters (Jacchia et al. 1973, Jakowski et al. 1991, Jakowski et al. 2002). The delay in the ionospheric electron content was attributed to the delay of the atomic oxygen concentration to follow solar radiation changes (Jakowski et al. 1991).

The present findings extend to a daily time scale the previous result (Vellante et al. 1996) showing a solar cycle variation of the local resonant frequency at L'Aquila (L = 1.56) with a minimum (~60 mHz) at solar maximum and a maximum (~90 mHz) at solar minimum. These results indicate that FLR measurements represent an important tool for understanding the coupling mechanisms in the complex atmosphere-ionosphere-magnetosphere system.

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