A statistical study of geomagnetic field line resonance properties

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Abstract

The propagation of ultra low frequency (ULF) waves, in the frequency range of 1-100 mHz, from the magnetosphere to the ground where they are usually detected is greatly affected by the Earth's ionosphere. The ionosphere presents a conducting interface between the magnetosphere and atmosphere. In this work magnetic field measurements observed in the topside ionosphere by low Earth orbiting CHAMP satellite and Hermanus (HER) ground station data set is used to test magnetohydrodynamics (MHD) theoretical predictions. This paper aims to illustrate the effect of the ionospheric currents on the propagation ULF waves in the Earth's magnetosphere. This is attempted by studying field line resonance (FLR) events observed at Hermanus and by CHAMP satellite on crossing HER latitude.

1 Introduction

Ultra low frequency (ULF) waves in the 1-100 mHz band are generated by processes involving the interaction of the solar wind and the Earth's magnetosphere. Our work is about the field line resonances (FLR) which is the most common source of the ULF geomagnetic pulsations observed during local daytime. In our work FLR refers to the single frequency driven magnetic field line resonances and continuum ULF field line resonances as discussed by [1]. ULF perturbations propagate toward the ionosphere where they are partially reflected and may be detected using ground-based magnetometers. One well known effect of the ionosphere on the ULF wave properties is a rotation of resonant magnetic field components when comparing the signal in the magnetosphere and the signal on the ground. In the case of uniform ionospheric conductivity the magnetic signal on the ground is rotated through 90^0 with respect to the magnetic field of the transverse Alfvén mode in the magnetosphere, because the signal below the ionosphere is proportional to the Hall current [2]. [3,4] showed that for a non uniform ionospheric conductivity the previously predicted 90^0 rotation between the magnetic field below and above ionosphere does not hold generally because the rotation angle depends strongly on the conductivity gradients.

2 Data

This study utilizes data obtained from CHAMP satellite that made observation orbiting the Earth in the F-region of the topside ionosphere. The satellite data is used in conjunction with Hermanus induction magnetometer magnetic field measurements. The low orbit of CHAMP satellite is rather special, being roughly a similar distance above the ionosphere as ground stations are below the ionosphere. This provides a unique opportunity of testing MHD theoretical predictions. The effect of ionospheric currents on the propagation of ULF waves can be studied by directly comparing the satellite and ground observations.

3 Events data base

In selecting events, instances when CHAMP traversed the Southern African region within 10^0 of longitude of HER, were determined. We established a database of events scanned from a two year (2002 and 2003) data set. The events that constitute the database were examined for typical FLR characteristics, which are the frequency Doppler shift and a degree of rotation between the resonant magnetic field components on the ground and satellite.

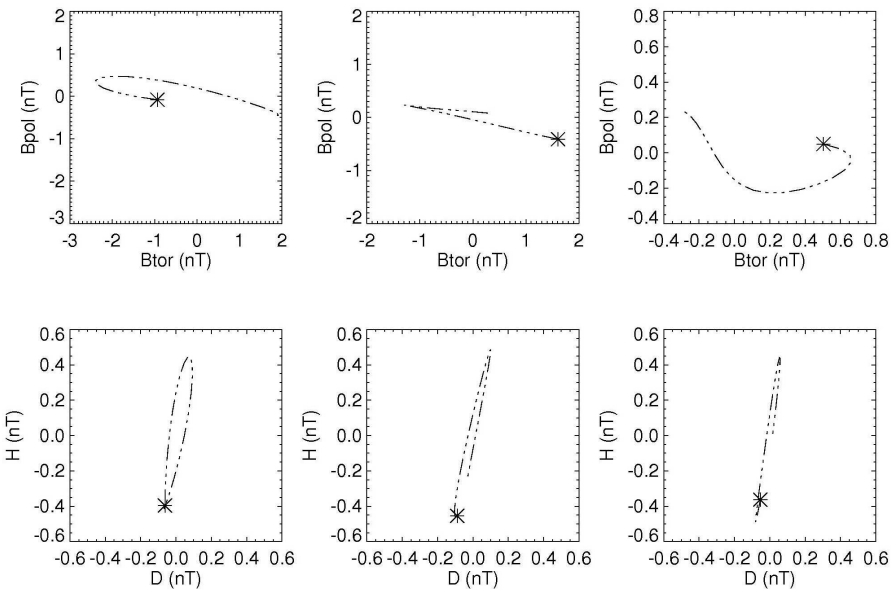


Figure 1: *CHAMP (top panel) and ground (bottom panel) wave hodograms for three consecutive 20 second intervals at the time when the satellite was passing over the Hermanus ground station (adopted from [5]).*

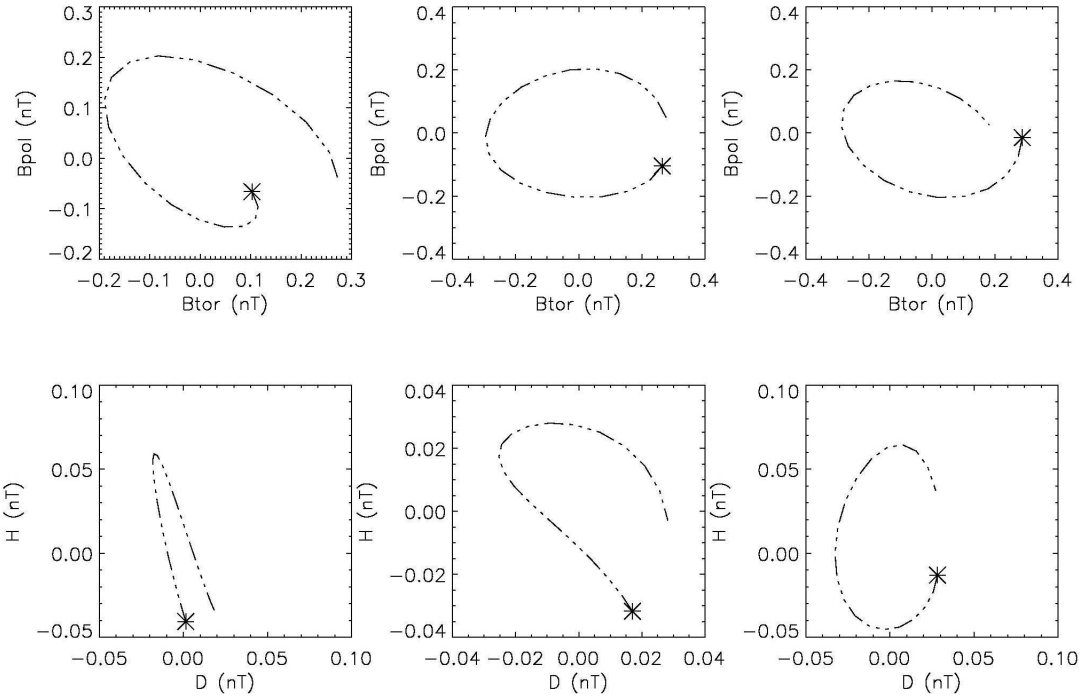
4 Results

Depending on the direction of the satellite the FLR frequency observed by CHAMP on crossing HER L-shell is Doppler shifted to lower frequency or higher frequency with respect to the frequency observed on the ground. For the poleward motion the Doppler shift is to lower frequencies whereas for the equatorward motion the Doppler shift is to higher frequencies. This observation is in agreement with [5,6] studies. [6] provide an explanation and derivation of this Doppler shift, which is due to the rapid rate at which a LEO satellite traverses the rapid phase change across the field line resonance region.

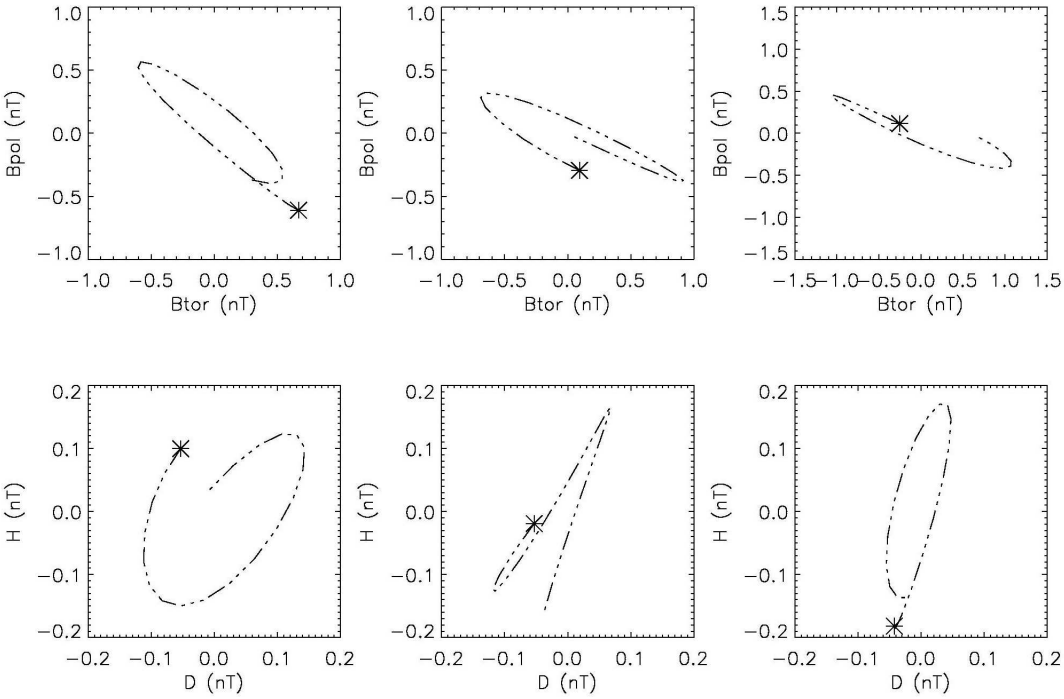
We observed a polarization Hodagrams characterisable in three ways: 90^0 *rotation, no rotation and not clear.* 90^0 rotation describes hodograms where 90^0 rotation of magnetic field components was observed as shown in Figure 6 of [5] (see Figure 1 above). Displayed in the figure are hodograms in the B_{pol}-B_{tor} plane for the satellite and in the H-D plane for the ground measurements for three consecutive 20 second time intervals during CHAMP's path over HER. First points are indicated by asterisks in the hodograms. The *no rotation* describes cases where polarization hodograms of the satellite and ground data have the same polarisation and consequently no rotation is observable. The *not clear* describes hodograms where the rotation is intermediate together with a mixture of polarisation sense (i.e. the interchange between clock wise and counter clock wise polarisation sense). Examples of polarisation ellipse hodograms that were considered to resemble *no rotation* and *not clear* characteristics are presented in Figure 2(a) and 2(b) respectively.

5 Discussion and initial conclusion

The polarization ellipses observed are discussed in terms of previously published theoretical studies of ionospheric conductivity. It is well know that 90^0 rotation is a direct result of the field-aligned currents associated with a shear Alfvén mode meeting the neutral atmosphere, where the curl of magnetic field is finite [7]. The modelling studies of [8] informs that in cases where there is only propagating compressional mode and no incident shear Alfvén mode there is no 90^0 rotation observable.



(a)



(b)

Figure 2: *Examples of the polarisation ellipse where the* 90^0 *rotation a) cannot be observed and b)cannot be clearly observed.*

At lower latitudes such as those considered in this study the rotation effects depends highly on the conversion coefficients of the MHD wave mode and consequently the ionosphere conductivities. At this stage we speculate that the *not clear* ellipses are associated to a variety of polarisation that depends on the altitude, conversion of shear Alfvén wave to compressional wave between the ionosphere and ground as shown by [8,9] for particular wave lengths.

6 References

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