A Global MHD Simulation of ULF Waves Activity in the inner Magnetosphere Resulting from CIR followed by ALFVENIC Fluctuations

Alves, M. V.[1]; Jauer, P. R. [1]; Souza, V. M. [1]; Pádua, M. B. [1]; Wang, C. [2]; Alves, L. R. [1]; Da Silva, L. S. [1]; R. E. Lopez. [3]; Vieira, L. E. A. [1]; Zhengkuan. L.[4]; Hui. L[4]; Gonzalez, W. [1]; Echer, E.[1]; Costa, J. E. R.[1]; Denardini, C. M. [1]; Rockenbach, M. S. [1]; Deggeroni,V. [1]; Medeiros, C. [1]; Marchezi, J. P. [1]; Silva, G. [1]; Grala, M. [1]; Schmitz, R. [1]

[1] National Institute for Space Research (INPE),
Av. dos Astronautas 1758 - Jardim da Granja, São José dos Campos - SP - CEP: 12227-010
[2] State Key Laboratory of Space Weather, National Space Science Center, Chinese Academic of Sciences, China
[3] Department of Physics, University of Texas at Arlington, Texas, USA
[4] National Space Science Center, CAS
pauloricardojauer@gmail.com; mvirginia.alves@inpe.br

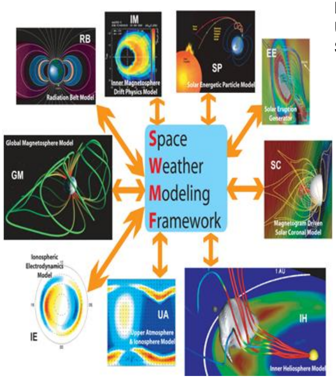
Introduction

The interaction between the disturbed solar wind and the geomagnetic field gives rise to different physical processes that can significantly affect technological systems as well as human life. The goal of this work is to investigate the role of a complex solar structure, i.e., a corotating interaction region (CIR) followed by solar wind's magnetic field Alfvénic fluctuations, in the generation of disturbances in the inner magnetosphere in terms of the power spectral density (PSD) of the ultra-low frequency waves (ULF) in the nightside, equatorial region. There are several studies that show the correlation between fluctuations of solar wind's magnetic field and plasma parameters characteristic of CIRs and Alfvénic fluctuations and the corresponding generation of ULF waves in the internal magnetosphere. However, some issues remain. Namely, during such a complex event it is not straightforward to decisively say which solar wind parameters or which combinations thereof are most effective in causing disturbances in the inner magnetosphere, or how each part of the complex interplanetary structure influences the most the temporal evolution of the magnetosphere.

Methodology

We use global MHD simulations to address some of these questions. Firstly, we use the magnetic field and plasma parameters of a real complex CIR+Alfvénic fluctuations event, (April 20, 2013), as input to the SWMF/BATS-R-US code. With the model outputs the we calculate the PSD of ULF waves in the inner magnetosphere, nightside, equatorial region. By separating the complex event into its constituent parts we build a synthetic magnetic field and plasma profiles based on the physical parameters that characterize each of these parts. The MHD code is then fed with each new synthetic profile to provide ULF PSDs that are compared with those from the simulation with real solar wind inputs.

MHD Simulation-SWMF/BATSRUS



Based on Tóth et al. 2005

Center for Space Environment Modeling
University of Michigan
SWMF/BATSRUS.

MHD is based on well-established physical theory

Physical domains coupled to this event

Global Magnetosfera GM:
33 R_E upstream and about 225 R_E downtail.

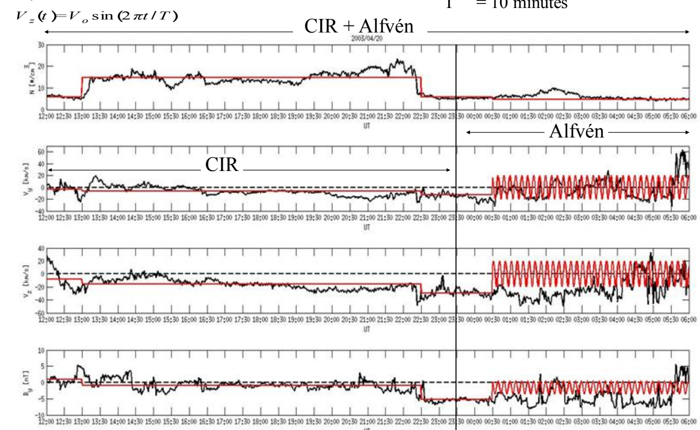
Inner Magnetosphere IM:
Rice Convection Model (RCM) Wolf et al, 1982, Toffoletto, 2003

Ionospheric Electrodynamics IE:
Ridley et al, 2004, Ridley and Liemohn, 2002

Build scenarios to aid in the interpretation of satellite measurements

$$B_y(t)=B_{avg}+B_o\cos(2\pi t/T)$$
$$B_z(t)=B_{avg}+B_o\sin(2\pi t/T)$$
$$V_y(t)=V_o\cos(2\pi t/T)$$
$$V_z(t)=V_o\sin(2\pi t/T)$$

B_{avg} = -1.5 nT
B_o = 2.0 nT
V_o = 20 km/s
T = 10 minutes

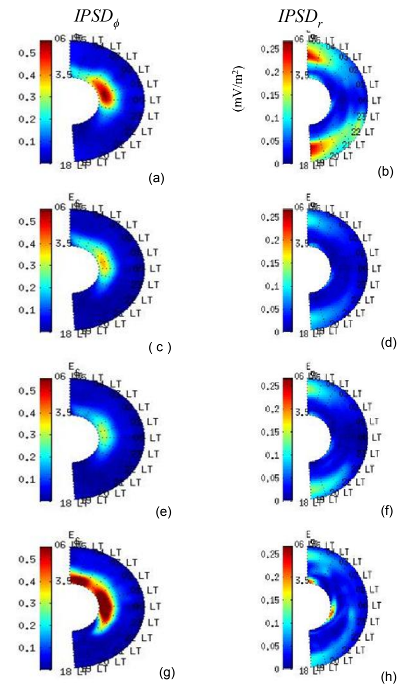


Black lines in the above figure represent the real solar wind data between 12:00 UT, 20 April 2003 and 6:00 UT, 21 April 2003 (ACE).
Red lines represent the synthetic profiles constructed with equations given above for magnetic field and velocity, with a period of 10 minutes and used as input for numerical experiments.

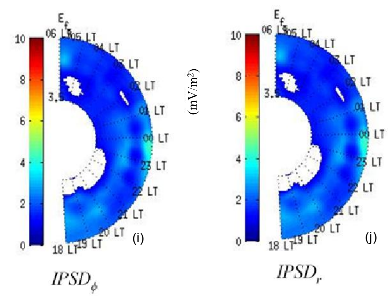
Results

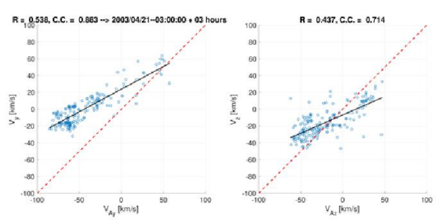
$$IPSD_{\phi,r} = \int_{0.5\,mHz}^{16.6\,mHz} E_{\phi,r}(\omega)\,d\omega$$

Comparison among IPSDs of the azimuthal Ephi and radial Er modes in the equatorial, nightside magnetosphere.
Panels (a) and (b) refer to the outputs of the simulation with real solar inputs (CIR+Alfvenic); panels (c) and (d) refer to outputs from the numerical experiments with synthetic solar wind input data (CIR+Alfvenic).
Panels (e) and (f) are the results for CIR synthetic input (11h) and (g) and (h) for the Alfvenic synthetic input (7h).



The panels (i) and (j) show the IPSD ratio between Real and synthetic results, CIR+Alfvenic.





Correlation Coefficient for the solar wind components Vy and Vz and magnetic field (VAy(z)) for the 3 last hours of the selected event. They are a good indication for the presence of Alfvenic fluctuations.

Conclusions

This numerical experiment will help us to understand which solar wind parameters contribute the most for the ULF waves activity in the nightside magnetosphere, as far as MHD simulations are concerned, and which combination of these synthetic parameters can reproduce the results obtained when running the MHD code with input data from the actual event. This work might also provide important information for future forecasting studies of ULF wave activity in the Earth's magnetosphere whenever the geospace is under the influence of recurrent events as the one analyzed here.

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