Association of Pc4-5 waves with near-equatorial electron fluxes during substorm activity

Christos Katsavrias[1,2] (email: ckatsavrias@noa.gr), **Alexander Hillaris**[2], **Ioannis A. Daglis**[2,1] **and Georgios Balasis**[1]

1. National Observatory of Athens, IAASARS, Penteli, Greece
2. National and Kapodistrian University of Athens, Department of Physics, Athens, Greece

Abstract

The Pc4-5 ULF waves (2 – 22 mHz) excited by substorm activity often coincide with quasi – periodic modulation of the near-equatorial electron population. In this work we examine the association between near-equatorial electron flux variation and Pc4-5 waves excited by substorm activity using multipoint observations. We apply cross-wavelet and wavelet coherence analysis to the magnetic field and flux time-series in order to obtain a comparison in the frequency-time space.

Data Selection and Methodology

We use electron differential fluxes from the Magnetic Electron Ion Spectrometer (MagEIS) instrument [Blake et al., 2013] as well as magnetic field measurements from the fluxgate magnetometer of RBSPA with a 4-sec resolution [Kletzing et al., 2013]. In addition, solar wind parameters with 1-min resolution are obtained from NASA OmniWeb.
A continuous wavelet transform with the Morlet wavelet as the mother function has been applied to analyze them in the time-frequency domain. Prior to the time-frequency analysis using wavelet transforms, a band-pass Butterworth filter with a frequency range of 6.9 to 22.1 mHz was applied to obtain the wavelet power spectra covering the Pc4 frequency range (typically between 7 and 22mHz). Then, wavelet coherence analysis was applied to the magnetic field and flux time-series in order to obtain a comparison in the frequency-time space and the association between near-equatorial electron flux and magnetic field variations.

Solar Wind and Magnetosphere Conditions

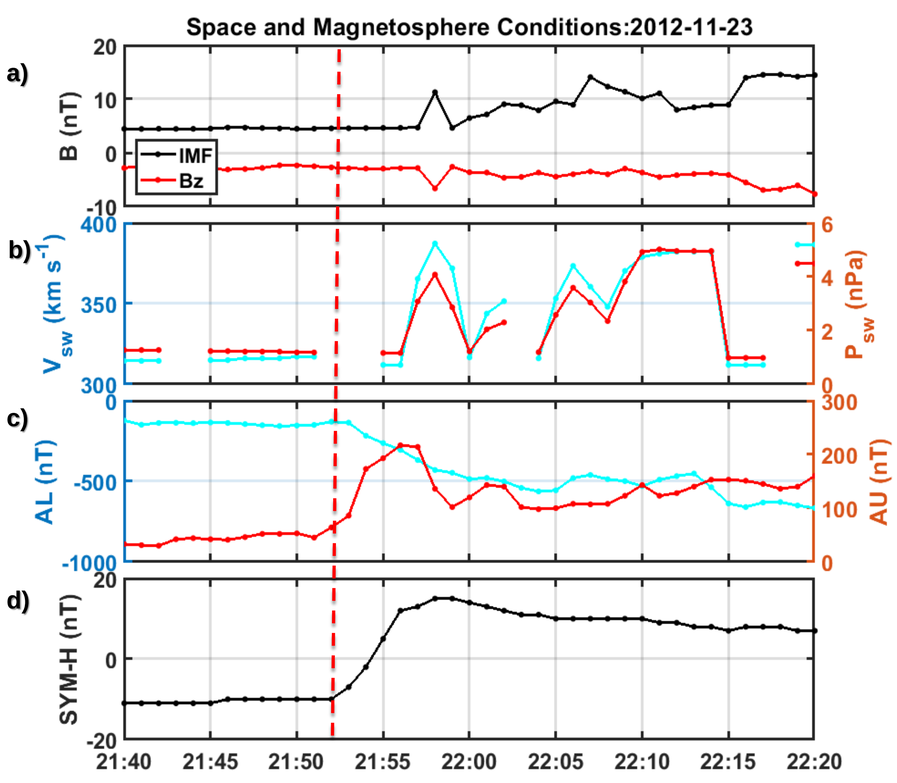

Figure 1. Overview of the November 23, 2012 solar wind and magnetosphere conditions.

In November 23, 2012 an ICME reached the Earth at 21:52 UT (dashed vertical line in figure 1). Signatures of the IMF disturbance are shown in figure 1a at 21:58 where Bz is decreased. At the same time pressure is increased from approximately 1 to 4 nPa while there is no significant change in speed (figure 1b). In addition, there is a positive increase of SYM-H index (figure 1d) that coincides with the onset of the substorm injection as indicated by AL index (figure 1c). During the arrival of the ICME, RBSPA was located at L~6.4 and MLT~5.2. This positioning allows us to observe the injected electrons and not an echo.

Modulation of Electron Flux by Poloidal and Toroidal Mode Waves during the SSC and Substorm Onset

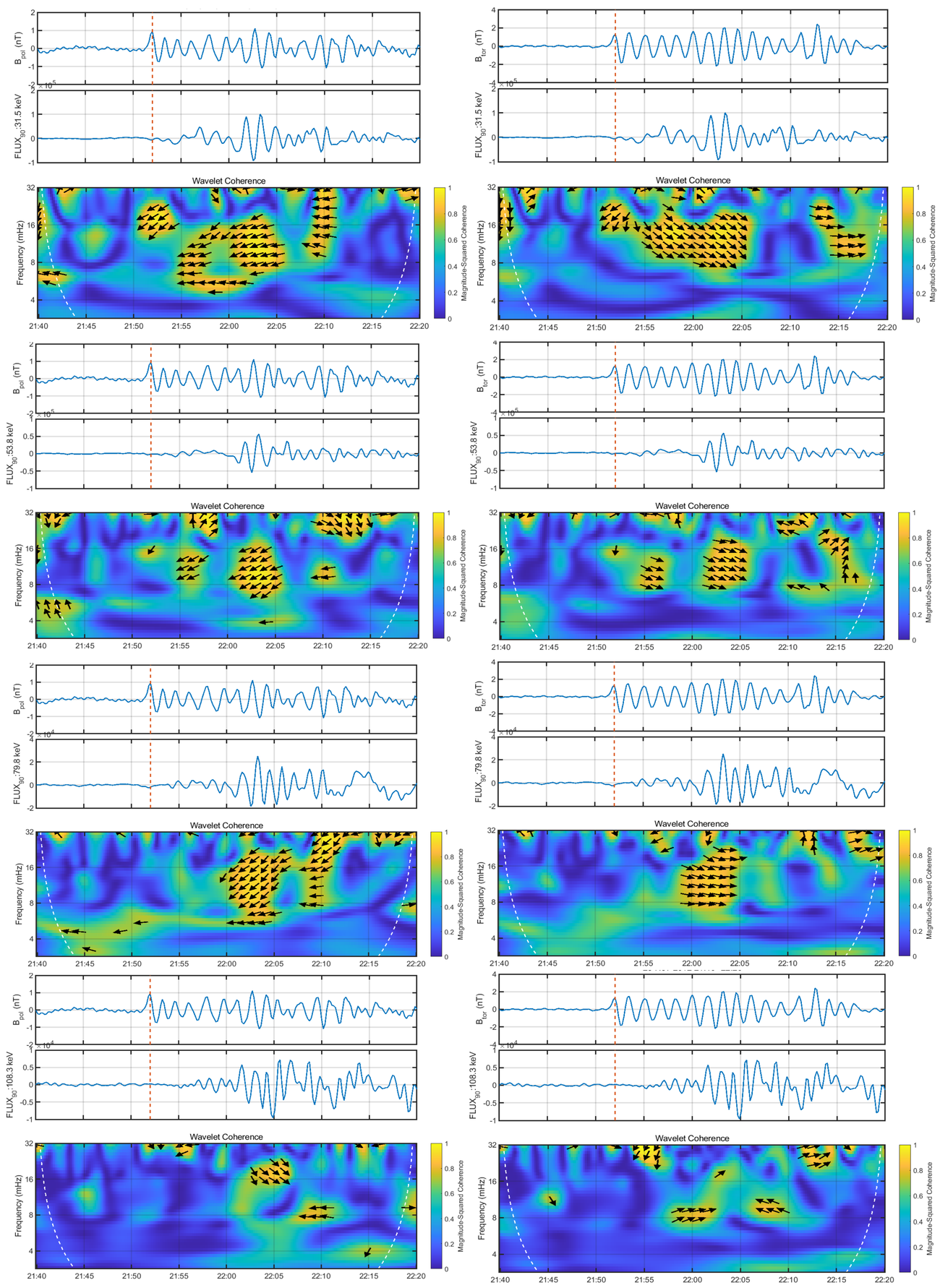

Figure 2. Left: Poloidal mode magnetic field and 90 degrees equatorial flux with their wavelet coherence for 4 energy channels of RBSPA respectively. Right: the same for toroidal mode magnetic field and 90 degrees equatorial flux.

Results for the Van Allen Probe-A are presented in Fig. 3 for each energy channel, and for both poloidal and the toroidal component of the magnetic field. These results indicate that there is a significant coherence of toroidal and poloidal component of the magnetic field with differential flux of 90 degrees. This clearly suggests modulation of electrons up to 100 keV by waves in the frequency range of 7–22 mHz.

Discussion and Conclusions

Zong et al. 2007 showed modulation of low energy electrons by toroidal Pc5 waves during a shock injection in the dayside magnetosphere. In the same context, Ren et al. 2017, using wavelet coherence showed an antiphase relationship at the magnetic equator is a common feature for drift-bounce resonant ions. Following that methodology we found that this association is present at the nightside magnetosphere and during a substorm onset.

- In detail, there is an in-phase relationship between toroidal mode waves (in the frequency range 7–22 mHz) and flux and an anti–phase relationship between poloidal mode waves and electron flux up to 100 keV all during the substorm onset.
- Based on the aforementioned test case we re-applied the methodology in a number of other events chosen based on the position of the Van Allen Probes (L>5.5 and 3<MLT<6) in order to observe the initial injection and not the echoes.
- Waves in the frequency range of 7–22 mHz were always present during the substorm onset but the corresponding modulation of electron flux was found only during the substorm onset of March 17, 2013 (06:00 UT) for which there was also a positive increase of SYM-H index that coincided with the onset of the substorm injection. A possible explanation could be that this modulation depends either on the geometry of the electron injection or the disruption of the cross-tail current.
- We foresee further analysis including electric fields pitch angles different than 90 degrees.

References

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