

Interactive comment on “Statistical study of ULF waves in the magnetotail by THEMIS observations” by Shuai Zhang et al.

Anonymous Referee #1

Received and published: 8 June 2018

General comments

This paper presents results from a statistical study of ULF waves in the Pc5-Pc6 frequency range in the magnetotail using magnetic field and plasma data from instruments onboard the THEMIS satellite during 2008–2015. Azimuthally oscillating waves and radially oscillating waves are studied separately. The authors found that in the near-Earth magnetotail the dawn-dusk asymmetry of wave occurrence is observed only in the case of radially oscillating waves. In the far magnetotail, they reveal a higher occurrence rate during post-midnight magnetic local times than during pre-midnight, and that the peak frequency of waves decreases with increasing radial distance from Earth. A majority of events in the near-Earth magnetotail are standing waves, while these represent very small percentage of the events in the far magnetotail. No dawn-dusk

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asymmetry could be found in the wave frequencies. Finally, the authors studied the effects of solar wind parameters and geomagnetic activity, and found that ULF wave occurrence is favoured by high solar wind speed, high solar wind pressure variability, but quiet to moderately active geomagnetic activity.

Overall, the paper is well-written, the reasoning is clearly exposed, and it reaches substantial conclusions. Below are a few specific comments which could be considered to improve the manuscript before final publication.

Specific comments (major)

(I) It would be good to have a figure in the same format as Figure 3 showing the number of events in each bin, both for azimuthal and radial oscillating events. Indeed, the text mentions on several occasions that a given bin should be considered with caution due to the small number of events it contains. In particular, such an additional figure could help in analysing Figure 4, as one might want to be cautious in drawing conclusions with so many blank bins in this figure.

(II) l. 327: "solar wind dynamic pressure (P_d) and the IMF B_z values were also examined (not shown)." → If the results on the dynamic pressure are mentioned in the conclusion (see l. 386), I would recommend to show the analysis of these parameters in the paper.

Specific comments (minor)

- l. 42: I suggest to give the frequency range for ULF waves from the very beginning of the introduction.
- l. 69: The full name of THEMIS should be given when mentioned for the first time after the abstract (see AnGeo guidelines: https://www.annales-geophysicae.net/for_authors/manuscript_preparation.html).
- l. 74: Please define MLT.

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- l. 76 and 78: "Susumu Kokubun (2013)" → please check the reference. I think it should be "Kokubun (2013)", and in the reference list it should appear as "Kokubun, S. (2013). ULF waves in the outer magnetosphere...".
- l. 82: Pi2 should be defined.
- l. 108: It could be worth briefly defining the GSM coordinate system here.
- l. 120: I assume Dp stands for "dynamic pressure"; perhaps it would be better to make it fully clear to the reader.
- Figure 2: I would suggest that, for a given event (A/B), the three components of the velocity, magnetic field, electric field should have the same y-axis limits. This would better emphasise the azimuthal or radial nature of the oscillations. This could also be done for the components of the PSD of the velocity, as the relative importance of the peaks would be immediately visible, without needing to look at the scale for comparison. An exception should obviously be made for panel (d2), as the Bz range for event B is very large.
- l. 174: "calculated by dividing the total event times by the total observation times" → do you mean the total *number* of events/observations? Or the total *duration* of events/observations? This wording may be ambiguous; please rephrase.
- l. 177: "For azimuthal oscillating events, there is no clear dawn-dusk asymmetry in the occurrence rates" → based on Figure 3, this statement seems a bit too strong, since high occurrence rates (red colour) span within 18–20 MLT on the duskside vs 5–6 MLT on the dawnside. Perhaps rephrasing this statement into something like "For azimuthal oscillating events, the dawn-dusk asymmetry in the occurrence rates is less clear than for radial oscillating events" would be better. Similarly, this statement should also be made less strong in the conclusion and abstract.

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- I. 202: "the frequency can be as low as 0.55 mHz" which is the lower frequency in the Pc6 band retained in this study. Could there be waves with even lower frequency observed? To my knowledge, there is no upper limit in the period of Pc6 oscillation (see Saito, T. (1978), Long-period irregular magnetic pulsation, Pi3, Space Sci. Rev., 21(4), 427–467, doi:10.1007/BF00173068), so it could be interesting to check whether pulsations of even lower frequency can be identified.
- I. 226: "The second row shows the 1.26-3.26 mHz (Fig. 6a) and 2.03-4.03 mHz (Fig. 6b) band-pass filtered Ba and Er components" → how were those frequency bands selected?
- I. 319-320: The calculation of the normalised event number does not seem fully clear to me. Is it so that the number of events is divided by the proportion of solar wind speed within a given bin to the total duration of solar wind measurements? Or are events binned according to the mean/median solar wind speed at the time when they were observed? Please rephrase this explanation.

Copyediting and typesetting

- I. 57: "primarily" being an adverb, it cannot be used in this context. Instead, one could write, for instance, "Pc5 and Pc6 waves are the most common waves observed at high latitudes and in the magnetotail."
- I. 60: "nightside" is generally written in a single word (same for dawnside, day-side, duskside...)
- I. 67: "the both occurrence and frequency distributions..." → "both the occurrence and frequency distributions..."
- I. 102, I. 201: earth → Earth

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- l. 106: sub-solar → subsolar
- l. 108: "whose X axis **is** rotated"
- l. 145: "to satisfy **the** criteria mentioned above"
- l. 154: "of **the** three components"
- l. 260: "the magnetic field lines **s** in the nightside **are** very stretched"
- l. 276: "K-H instabilities are **more** inclined to occur in the dawnside than in the duskside"
- l. 278: "more events are needed **to** further study the definite reasons"
- l. 286: Alfven → Alfvén
- l. 321: "the ULF waves occurrences increase with" → "the ULF wave occurrence increases with"
- l. 322: a sources → a source
- l. 324: "the waves occurrences are higher" → "the wave occurrence is higher"
- l. 327: occurrence
- l. 336: (Forsyth et al., 2015) → Forsyth et al. (2015)
- l. 379: "the peak frequency decreases **with increasing** radial distance"
- l. 383: "the frequencies for all the events in this paper do not show obvious dawn-dusk asymmetry **contrary to results from** previous studies for waves in the inner magnetosphere" (the original phrasing can be ambiguous and interpreted the other way round)

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- l. 387: maybe → may be
- l. 389: "that the ULF waves **are** most likely to occur"

Interactive comment on Ann. Geophys. Discuss., <https://doi.org/10.5194/angeo-2018-39>, 2018.

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