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Comment on angeo-2021-47

Anonymous Referee #1

Referee comment on "Quantifying the non-linear dependence of energetic electron fluxes in the Earth's radiation belts with radial diffusion drivers" by Adnane Osmane et al., Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2021-47-RC1, 2021

Summary:

The manuscript entitled "Quantifying the nonlinear dependence of energetic electron fluxes in the Earth's radiation belts with radial diffusion drivers" by Osmane et al revisits a highly cited case study (Rostoker et al., 1998) (1) to quantify the strength of the statistical dependence between ULF wave power and seed and relativistic electron fluxes measured at GEO and (2) to test for the presence of nonlinear dependence (l.70-73).

To do so, the mutual information and the Pearson correlation coefficient are computed for each combination of:

- 1) (*) ground or (*) geosynchronous ULF wave power and
- 2) (*) seed (130 keV) or (*) relativistic (1.2 MeV) electron fluxes at GEO

for the 2 events analyzed by Rostoker (26 days in 1993 and 91 days in 1994, l.203), with and without a 24 hr window moving average, for time offsets varying between -100hr and +100hr (see Fig. 4- Fig.11, with the max values for each instance summarized in Table 1). ULF data is Augsburg ULF indices. Electron fluxes are from the synchronous orbit particle analyzer (SOPA) instruments onboard multiple GEO spacecraft.

The findings are that "the Pearson and the mutual information are both statistically significant" (l. 327), corroborating Rostoker et al. (1998)'s finding that ULF wave power and relativistic electron fluxes are statistically dependent (l. 8-9). It is also found that the statistical dependence between ULF wave power and 130 keV flux is larger than for relativistic fluxes (l. 347). Because the "adjusted correlation" is found to be larger than

the Pearson correlation, the results "indicate that the response of relativistic electron fluxes can be a combination of linear and nonlinear dependence" (l. 369). More generally, the paper calls for "incorporating data analysis tools that can quantify and distinguish between linear and nonlinear interdependencies of various solar wind drivers" (l.12-13, l. 391-392).

General Comments:

The work revisits cases discussed in a highly cited paper using a new approach (higher time resolution with a "comparable data set" - l.212, correlation and mutual information quantification). Proper credit is given to related works. The contribution is clear and it is compared and contrasted with other published results (e.g., l.326-346). In that context, the work is fairly important: It represents an incremental advance to the current state of knowledge of the field.

That said, the written presentation of the work lacks conciseness. An effort in synthesis would greatly benefit the readability (thus accessibility and potential impact) of the manuscript. This should be done, if only to do justice to the research work.

Specific Comments:

1) Section 2 provides~ 100 lines of generalities ("a brief but self-contained tutorial on the Shannon entropy and mutual information for a reader who is not familiar with information" l.84-85). Yet, its value for the remainder of the manuscript is unclear. For instance, Fig. 1 provides the results of a numerical test that appears to be unrelated to the paper. In addition, the formulas used to determine the quantities plotted Fig.4-Fig.11 are not explicitly provided. One way to address this comment could be to shorten the Section 2, retaining only the descriptions of the formulas that are used in the ULF/Eflux data analysis, and referring the interested reader to works already published on this topic (e.g. Wing et al., 2016 and references for information theory lectures). Another way could be to create an appendix for supplementary material.

2) The main results are presented as a list of 8 different figures (each composed of 4 different panels). Yet, there is little difference between the figures: They all appear to provide similar information (namely, that there exists a significant dependence between waves and particle fluxes). Fig.1 a)-b) is enough to illustrate the approach and the point of the paper is conveyed in Table 1. In that context, everything else could be provided as supporting material. If all 32 panels are really necessary to convey the message of the work, this needs to be explained at the beginning of Section 4.