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Nonlinear Processes in Geophysics
Discussions

Interactive comment on “Characterization of HILDCAA events using Recurrence Quantification Analysis” *by* Odim Mendes et al.

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article

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Characterisation of HILDCAA events using Recurrence Quantification Analysis

by

Mendes et al.

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Discussion paper

Reviewer #2
comments and answers

Referee = **R** and Authors' answer = A

General comments of the authors:
Initially, we thank the Reviewer for the suggestions and encouragement. A PDF of the paper revised is attached and presents the complete information (In it, the color blue indicates parts of the text revised or even sections completely revised).

R: This paper opens an interesting possibility to apply the RQA to analyze dynamic properties of auroral activity in HILDCAA or in response to different heliospheric drivers. Unfortunately, the paper does not provide physical interpretation of the results.

A: This aspect of the paper has been improved to contribute to the application of the non-linear methodology and the interpretation of the results obtained. Dealing with the integration of three areas (Space Physics, data analysis, and methodology of non-linear science), the authors revisited the paper adding more details (in all sections) to provide an attractive and acceptable work.

R: Specifically, physical meaning of information presented in Figures 5 and 6 is not discussed.

A: The characteristics of the typology and texture present in the RP are the key points of the interpretation; however, the visual interpretation of RPs requires some training experience, usually done from standard systems or data libraries. For instance, as described in Marwan et al. (2007) and in the RP and RQA website http://www.recurrence-plot.tk:
(*i*) stationary processes are associated with a homogeneous distribution of points in

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RP;
(*ii*) periodic processes present cycle patterns (check board) where the distance between periodic patterns corresponds to the period;
(*iii* long diagonal lines with different distances to each other reveal a quasi-periodic process;
(*iv*) non-stationary processes can present interruption on the lines; this can indicate as well some rare state, or RP fading to the upper left and lower right corners also indicating trend or drifts;
(*v*) single isolate points demonstrate heavy fluctuation in the process, in particular, if only isolate points occur an uncorrelated or anti-correlated random process are represented;
(*vi*) evolutionary processes are illustrated by diagonal lines, then the evolution of states is similar at different times, however, if it has parallel lines related to the main diagonal, the system is deterministic (or even chaotic, if they occur beside single lines), and if the diagonal lines are orthogonal to the main diagonal, or the time is reversed, or the choice of embedding is insufficient;
(*vii*) long bowed line structures express evolution states that are similar at different epochs although they have different velocity (the dynamics of the system could be changing);
(*viii*) vertical and horizontal lines/clusters are evidence that the states have no or slow change for some time, which point to a laminar state.

From Figures 5 and 6, the RPs highlight the recurrences in the signal records showing differences in the dynamical patterns between the HILDCAA interval and the quiet period. To the both systems, the analyses on the large scale patterns in the plots, designated as typology, denote that they are of the disrupted kind, i.e., with abrupt changes in the representation of the dynamics. However, the analysis of the small scale patterns, designated as texture, denotes a more complex dynamics in the HILDCAA event than the one in the quiet interval.

However, the RQA offers a more objective way for the investigation of the considered systems. The density of points, clusters, and structures patterns present in the RP can identify the local behaviour of the analysing data.

R: I have a problem with the claim that dynamic properties of HILDCAA-driven activity are "unique". There are distinct differences with the quiet-time study, but uniqueness can be shown only in comparison with other non-HILDCAA driven auroral activity. For instance, analysis of CIR/HSS storms without HILDCAA could be helpful.

A: We improved the paper with the extension of data sets concerning the Auroral Electrojet AE index adding other distinct interplanetary conditions. It allows analysis comparisons more complete including, for instance, the suggestion of the Reviewer to analyse CIR/HSS storms without HILDCAAs. The interpretation of "unique event" required clarification. In fact, a modification of the result based on the result of the analysis was necessary. The new information: "The HILDCAAs seem unique events regarding a visible, intense manifestations of interplanetary Alfvenic waves; however, they are similar to the other kinds of conditions regarding a dynamical signature (based on RQA), because it is involved in the same complex mechanism of generating geomagnetic disturbances."

We reformulate the plot of the dynamical comparisons in the paper. The interpretation was reformulated based on a data set extended to our purpose. In the plot attached here as a coloured figure, we present a normalised representation of the RQA parameters for Auroral Electrojet AE indices: in HILDCAA events ($\circ$), in CIR/HSS not followed by HILDCAA (x), in a global geomagnetic disturbance scenario (*), and in the geomagnetically quieter intervals (+).

In short, there are distinct clustering, identified by RQA, of the dynamical behaviours recorded on the ground produced by the interplanetary medium conditions: one regarding a geomagnetically quiet condition regime and another regarding an ef-

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fective disturbed interplanetary regime. The RQA results identify similar dynamical behaviours for HILDCAA events and the other else disturbed cases.

R: I encourage the authors to continue and extend the study with the focus on understanding physical processes behind different types of auroral activity.

A: The authors added other data to extend the analysis.

References

N. Marwan, M. Carmen, M. T. Romano, and J. Kurths. Recurrence plots for the analysis of complex systems. *Phys. Reports*, 438:237–329, 2007.