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Interactive comment on "Nonlinear analysis of the occurrence of hurricanes in the Gulf of Mexico and the Caribbean Sea" *by* Berenice Rojo-Garibaldi et al.

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Interactive comment on "Nonlinear analysis of the occurrence of hurricanes in the Gulf of Mexico and the Caribbean Sea" by Berenice Rojo-Garibaldi et al.

Anonymous Referee #1 Received and published: 31 October 2017

The manuscript's goal is to evaluate the chaotic nature of a hurricane time series reconstructed using historical data and a hurricane dataset. This manuscript presents several problems that I will try to elucidate here: 1) Conception of the study: -it is not clear how the dataset analyzed is constructed and what are the relations with the

HURDAT database. No comparison with already existing hurricane datasets is shown.

In the article by Rojo-Garibaldi (2017), the way in which the time series of the hurricane was constructed is explained in detail. The series was elaborated taking the existing information from different hurricane databases. HURDAT is a hurricane database of the NOAA with data from 1851 to 2016. All hurricane from the Gulf of Mexico and the Caribbean Sea were extracted from these dataset. Data prior to HURDAT were obtained from various databases and were considered valid if they were mentioned in at least two different databases. Since the series was built with data from these series, it is not valid to compare the constructed series with the same HURDAT series.

-Figure 1: is the linear ïňĄt showing a signiïňĄcant reduction in the number of hurricanes? If the ïňĄt is signiïňĄcant, this means that your analysis cannot be performed because the series would be issued from a non-stationary process.

Yes, the linear adjustment shows a reduction in the number of hurricanes. Previous results regarding the number of hurricanes shows an increase in the number, but these studies were conducted with shorter series, the same interval of time used in those studies was analyzed here, and the results showed the same pattern as those reported by those authors, once the time series was extends the trend changes, this is one of the results obtained by Rojo-Garibaldi et al. (2017). In our analysis we start by considering that the time series analyzed is generated by some dynamic system, that has a finite time horizon, that is, for large time series the correlations between the states of the system fall exponentially. It must be taken into account that this requirement may not be valid for critical dynamic systems, which are characterized by dynamic correlations and statistics that decay very slowly, as an inverse power of time. When working with stationary dynamic processes, it does not make sense to take the temporal values in a range higher than the finite time horizon of the system, that is, the one above which there is no correlation between the values of the dynamics. If the adjustment is significant, the series may not be stationary, but other tests are required to be certain and that is why several tests were applied, not only the adjustment. The results show that it is possible to do the nonlinear analysis and that the results obtained here are valid.

-Why the authors perform a nonlinear time series analysis on the time series on the number of hurricanes?

This is a very interesting question, because it was the main reason for this study and the answer is very simple, because we are interested in model the generative process that gives rise to the complex system. In this case, the question would be: what is the simplest model that is able to explain the observed data?

What is supposed to be the ubderlying “dynamical system” that generate the hurricanes count in certain regions?

This is the key question of most of the studies related to predict the number of hurricanes and its intensity from one year to the next. DeMaria (2008) in the introduction of his article "A Simplified Dynamical System for Tropical Cyclone Intensity Prediction" makes an excellent presentation of the problems and methods used to treat this problem. We start from a different approach, we try to find the nonlinear properties of the system and establish the minimum number of variables required to construct the simplest model that can explain the behavior of the observed data.

How can the “attractor” of the number of hurricane occurrences give any information on the predictability of the phenomena as claimed at the end of the introduction?

As mentioned in the manuscript "The attractor dimension was mainly obtained because this value tells us the number of parameters or degrees of freedom that are necessary to control or understand the temporal evolution of our system in the phase space, and helps us to know how chaotic our system is. . . "

-The phase space reconstructions in Figure 2 shows a noisy ïňĄxed point structure. This is coherent with the fact that the hurricane occurrence seem to be Poisson or Compound Poisson distributed.

As mentioned in the manuscript "We observed that the points are scattered in the constructed plane, indicating that there is a chaotic behavior", but we also say "However, the most robust method to identify chaos within the system is the Lyapunov exponent". The Lyapunov (A) exponents were obtained using the Kantz and Rosenstein methods taking the time lag and the embedding dimension. The Kantz (1994) method using a value of m = 4 and r = 9 give us an exponent of A = 0: 48392 and form = 5 and r = 10 the exponent was of A = 0: 48392. Since A is a positive value, it was inferred that our system is chaotic. In addition, the value of A for both imbibing dimensions was the same, suggesting that our result is accurate.

In this manuscript several methods were used, which seems to be redundant, this was because as the referee says, "the hurricane occurrence seems to be Poisson or Compound Poisson distributed", this part "seems to be" requires a very careful analysis.

The rest of the analysis just show trivially the consequences of this. 2) The language: I won’t comment here on the English language but only on the use of scientiïňĄcally wrong expressions. Just to make some example: - Hurricanes are not complex systems. They are extreme phenomena that occur in a complex dynamical systems (the climate system).

This comment reflects how complex and complicated the topic is. Hurricanes, in fact, are extreme events that occur in a complex dynamic system (the climate system) and, in turn, hurricanes are dynamically complex systems, both are true and both have different behaviors from a non-linear point of view. That is why it is possible to predict the trajectory of hurricanes with a good approximation, but the number and intensity of hurricanes that will occur from one year to the next is a more complex problem.

- Line 7-8 chaotic edge of what?

The concept of chaotic edge is relatively new and applies to systems in which an individual has a chaotic behavior while the sets of individuals of the same species have a different behavior, as is the case of ants, bees and, in our results the case of hurricanes.

- The last sentence seems broken or is impossible to understand what you mean by “category”. Do you mean hurricane strength?

The intensity of hurricanes is measured by the Saffir-Simpson index and is a scale that measures the intensity (or category) of hurricanes based on wind speed.

- “Lyapunov exponent is a key point”: actually it is a dynamical systems metric.

The fact that it is considered a dynamical systems metric it does not take away the importance, because as it is said in the manuscript "The Lyapunov exponent is invariant under soft transformations, because it describes the long-term behavior, providing an objective characterization of the corresponding dynamics (Kantz and Schreiber, 2004). The presence of chaos in dynamic systems can be solved by this exponent, since it quantifies the exponential convergence or divergence of initially close to the state space and estimates the amount of chaos in a system (Rosenstein et al., 1993; Haken, 1981 Wolf, 1986). . . "

- What is a “chaotic movement”?

The concept of chaotic movement is widely discussed in the specialized literature and it is not our intention to enter into a wide discussion, we will only say that a chaotic system is entirely deterministic, while a random system is completely non-deterministic

3) The references are not updated: they are mostly coming from the (excellent) scientiïňĄc knowledge of dynamical systems in the 80s/90s. There are only very few references from 2000. Of course, since this date there have been several improvements to the methodology and the problems the authors want to address but they seem completely unaware of this body of literature.

The referee is right and the observation is appreciated. Most of the literature refers to the basic definition of the applied methodologies since the existing one regarding hurricanes refers mostly to the study of the non-linear dynamics of training and the

evolution of hurricanes and not to the nonlinear analysis of time series of the occurrence of hurricanes, however, there is literature that can be used, although it does not refer explicitly to the problem in question.

4) The conclusions are practically inexistent (this problem is certainly related to the wrong conception of this study, as detailed in my point 1)

The most important conclusion that we obtain and, which is the one that is reported in the manuscript, is that the time series of the number of hurricanes shows that the system is in a chaotic edge. This is one of the reasons why it is so difficult to predict the number of hurricanes over time. Future studies on this subject should be done considering this condition.

For all these reasons, I ïňĄrmly advise against publication nof this manuscript in NPG. I encourage the authors 1) to analyze different time series than the number of hurricanes in the Caribbean region to infer dynamical properties, 2) to review the recent literature on dynamical systems metrics 3) To use carefully the scientiïňĄc jargon pertinent of dynamical systems community.

We appreciate all the comments, which we will use to improve the manuscript.

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