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Discussions

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Interactive comment on "Defining scale thresholds for geomagnetic storms through statistics" *by* Judith Palacios et al.

Judith Palacios et al.

judith.palacios@uah.es

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Dear M.A. Hapgood (Reviewer 1)

Thank you for your careful revision of the manuscript. Your suggestions will improve its quality. All remarks are carefully explained below.

General comments

a. Thanks for the comment. We have included the following explanation to link with the following paragraph and explanation to link the GIC production, as an effect of the adverse space weather conditions, with the cause, that are the geomagnetic disturbances. It also appears summarized in the corrected version of the

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Discussion paper

manuscript.

The derivative of *LDiñ*, named *LCiñ*, is highly correlated with the geomagnetically induced currents records from the Spanish Power Company (Cid et al., 2016). Indeed, the recorded GICs, which depends on the substation, show a linear relationship with the *LCiñ*. This links GICs with the index derivative.

Being aware of these facts, and knowing that accurate real-time monitoring according to the needs of the final users is key, the Spanish Space Weather Service (SeNMEs) in 2014 introduced the G- and C-scale, for *LDiñ* and *LCiñ*, respectively.

The G- and C- scales in SeNMEs are related to the natural phenomena involved, and not directly related to the potential consequences (it is not a effect-based scale). To properly suit to the practical task of managing the space weather risk to vulnerable systems, every system shall establish their own risk protocols based on the potential consequences expected when a threshold is surpassed.

As an example, the differences between a scale related to a natural phenomenon and that related to the risk can be understood considering weather and climate events, for example, extreme rainfall. The occurrence of a value of total cumulative precipitation at a given time scale above a threshold value near the upper end of the range of observed values will be considered as an extreme rainfall event. However, the potential occurrence of flooding, including risk to human life, damage to buildings and infrastructure, will not only depend on the total cumulative precipitation, but also, on the orography of the place where the rain is falling.

b. Thanks for the comment. We have revised the literature provided by Reviewer 1. For comparison between the GICs measured in Spain and others measured in equivalent magnetic latitudes, we refer the reader to Cid et al. 2016, STO-MP-SCI-283 (already referenced in the manuscript), which shows very similar GIC values to Matandirotya et al. 2016, minding those 5-min averages on GIC values. We have updated the text to include the reference of Ngwira et al. 2015, which quotes the papers by Pulkkinen et al. 2015, and other authors who have noted the importance of local disturbances. Some of these references does not seem to be directly comparable, as Divett et al. 2017, where New Zealand in the southern hemisphere is at the same geomagnetic latitude as Edinburgh and it is a slender island; or Marshall et al. 2017, about GICs in Australia (this country is very large, with important differences in latitude). Some other references on modelled GICs may yield overestimated values, and direct GIC measurements are more scarce. Most importantly, we may consider that the power network structure and its geological and geographical differences are some of the most relevant factors on GIC production.

About the thresholds mentioned in the literature, we have to remind that usually they are defined as return periods on 100- 1000-y, or used to compute the return periods through a threshold, defined ad-hoc high enough to be used by the peak-over-threshold method, and then fitted with a Generalized extreme value distribution, GEV (Pulkinnen et al. 2015). Most of the Reviewer 1's recommended references are thresholds derived for high latitudes, or different industry safety levels and ranges. Even the same geomagnetic latitude cannot guarantee an equivalence in the GIC magnitude order, since they are very dependent on power grid and geology.

As Reviewer 1 has noticed, the method described in the manuscript is applicable to any data range, amount, and index, since only data-related best fit distributions and their intersects will define the thresholds.

Please also refer to Points 9 and 10.

Specific comments

1.- Thanks for the comment. The text has been updated to reflect it.

2.- Thanks for the suggestion of Sugiura and Kamei, 1991. It has been properly included.

3.- Thanks. It has been changed accordingly to emphasize that is an index that can be computed for any observatory.

4.-5. Thanks for the comment. These two points have been clarified in the text. The corresponding comments on K and A, A_p and a_p have been included in the corresponding paragraph.

6.- G scale and K_p equivalence is set in the text in the Introduction.

7.- Now $SYM-H$ has been presented in the Introduction. To make the formulation of *LDiñ* clearer, we have included a paragraph in the 'Geomagnetic data' section comparing *LDiñ* to $SYM-H$ in selected storms.

8.- Thanks. We have added some of the suggested literature to the manuscript (see (b)).

9.- Thanks for the comment. Unfortunately we do not agree on the comment of removing the explanation about datasets. Statistically it is very important the data number and the subsequent distribution shape, and it can be modified due to the addition of more data. We can explain with a example: a sample of photons that arrives to a detector, when the amount is scarce, can be fitted by a poissonian (it is the assumed typical shape). However, when an important amount of photons gets into a detector, the distribution will take probably a gaussian shape. Therefore the amount of course modifies the distribution shape, and subsequently, many other parameters such the return period, which is directly dependent on the distribution choice.

We agree on the wealth of literature describing GICs and the recent advances on statistics that are directly applied to this field. Again, different distribution shapes may arise depending on the magnetic latitude, therefore thresholds should be local to be more precise. Reviewer 1 refers to some specific statistical treatments: when a binomial or peak-over-threshold is estimated, sometimes with clustering involved, only a limited number of events arise and it complicates the statistical treatment, as samples are more limited that way. It is not the case for the method presented in the manuscript.

10.- Considering the thumb rule of 5 times the data period, we could not reliably compute a 100-y return period since we have 15 years of data. Return periods are usually defined on binomial but recently poisson distribution or generalized extreme values distributions (considering peak over thresholds) have been used. It is computed directly by cumulative distribution functions CDFs through SFs (survival functions). These return periods can be considered as extrapolations of the distributions, and some caution is required when any scenario is projected with them. These scenarios may be better suited when fed with long-term solar and geomagnetic field data. This is the reason why we appreciate them but we do not focus on return periods.

11.- Q-Q plots have been introduced in the Discussion.

Technical corrections

Typographical issues.

1. Corrected.
2. We think it is meant on page 2, line 4. Corrected anyway.
3. Corrected. We meant ‘comprises’.

Best regards,

The Authors

Please also note the supplement to this comment:

https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2017-367/nhess-2017-367-AC1-supplement.pdf

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