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Natural Hazards and Earth System Sciences
Discussions

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

Anonymous Referee #2

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This manuscript presents a mathematical characterisation of the occurrence distributions of three global geomagnetic indices: the ring current indices Dst and SYM-H, plus the mid-latitude disturbance index Kp. It explores how well these distributions may be represented by a wide range of distribution functions, and then uses the fitted functions to derive a mathematically consistent set of scale thresholds for different levels of geomagnetic activity: moderate, intense and extreme. The authors then argue that these scale thresholds are useful as criteria to assess the vulnerability of technological systems to geomagnetic activity.

Major comments

This is an interesting approach in that the manuscript provides a statistical overview of the distributions of these three geomagnetic indices. However, it fails quite fundamen-

tally to engage with what is needed to assess the risks that geomagnetic activity poses to technological systems such as power grids. I would highlight three key points here:

a. most importantly, there is no evidence that any of these scale thresholds are associated with specific impacts on vulnerable technologies. I find it impossible to see how they can support the generation of truly actionable information to mitigate space weather, e.g. a nowcast that power grids operators could use as a trigger for mitigating actions such as bringing additional reactive power on-line (a classic action to maintain stable grid operation). These thresholds can, of course, be used as a general indicator of unusual conditions, but responsibility for action thresholds is left entirely with end user.

b. another important point is that there is no evidence that these scale thresholds are of use in wider assessment of space weather risks by decision makers in government or industry, or in assessing how to provide commercial insurance against those risks. Those assessments are fundamentally dependent on risk recurrence times, but the authors have explicitly avoided any consideration of recurrence timescales in constructing their scale thresholds (as noted in the penultimate paragraph of their section 1). Some examples to illustrate the importance of recurrence times in assessing risks: (a) the design of industrial systems will need to consider what risks may arise during the design lifetime of that systems (perhaps 50 years for a large power grid transformer that might be damaged by space weather); (b) government risk managers typically plan for worst case risks from natural hazards (e.g. flooding, pandemic flu, severe normal weather, as well as space weather) occurring on a 1-in-100 years timescale (though perhaps longer timescales for impacts on critical systems); whilst (c) insurers typically aim to be financially robust against risks from natural hazards arising on a 1-in-200 years timescale. The approach outlined in this manuscript offers no insights that can help with such risk assessments.

c. a third, perhaps more subtle, point is that these thresholds provide no insights into key features of geomagnetic activity that may lead to significant adverse impacts on vulnerable technologies such as power grids. Here I refer to features, usually with horizontal scales <= 500 km, that can drive high rates of change in the size and orientation of geomagnetic field, thus creating geoelectric fields with potential to disrupt electrically grounded infrastructures. This is a hot topic in the field and an area to which some of the authors have contributed (as shown by references in the manuscript). It is a key area for research: we need to better understand the spatial and temporal occurrence of these features so we can assess the risks that they pose. So the statistical thresholds developed in this paper could be useful if they could be related to the occurrence of such features. But, at present, I see no pathway by which that could be done. Minor comment

In section 3.2, the authors define thresholds in the index values by identifying levels of the index values where fitted distributions intersect the complementary cumulative distribution function or where there is an interaction of different fitted distributions. This method is not clear and needs more explanation. Please provide a more detailed explanation that justifies these thresholds and that can engage the wider readership of NHESS; if possible please provide some references that will be accessible to that readership.

Summary

I am concerned that this manuscript seeks to set thresholds against purely mathematical (statistical) criteria, without any consideration of other issues that reflect how the adverse impacts of space weather are assessed and mitigated. This approach is fine as a way to characterise the variability of space weather environment, but it provides no insights into when that environment poses a substantial risk to critical technologies, or what physics distinguishes the potentially damaging conditions. I recommend that the authors extend and adapt their analysis and their manuscript so that their statistical work and the resulting scale thresholds are guided by the engineering, risk assessment and physics issues that I raise above.

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