Geomagnetic Storms over the Last Solar Cycle

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Geomagnetic storms are periods of high energization of the Earth’s magnetosphere. If powerful enough, they can cause substantial damage to infrastructure that is crucial to modern life. By studying geomagnetic storms in the last solar cycle, I aim to answer the question “What can be learned from the most recent data collected on geomagnetic storms and how can we prevent catastrophe to infrastructure if intense geomagnetic storms occur in the future?” The main foundational work I am using to base my own research on is “Geomagnetic storms over the last solar cycle: A superposed epoch analysis.” I will emulate the analysis performed in that study but will focus on the difference in intensity and frequency of storms from the last solar cycle to this one. Then, I will compile potential methods—from a variety of sources—that can be used to prevent damage to Earth’s infrastructure should extremely powerful storms occur. After my research concludes, I will produce a paper that highlights the changes from the past cycle to this one and presents the preventative measures I have found. I am requesting $1,650 in funding to pay for the time I spend acquiring and analyzing data and creating the paper.

*Introduction*

Geomagnetic storms are one of many phenomena that occur due to the sun and the earth’s magnetic interactions. In “What is a geomagnetic storm?”, an in-depth study on geomagnetic storms, W. D. Gonzalez *et al.* characterize a geomagnetic storm as “an interval of time when a sufficiently intense and long-lasting interplanetary convection electric field leads, through a substantial energization in the magnetosphere-ionosphere system, to an intensified ring current sufficiently strong to exceed some key threshold of the quantifying storm *Dst* [disturbance storm-time] index” (W. D. Gonzalez *et al.*). Essentially, the magnetosphere, “the region around a planet dominated by the planet’s magnetic field…[and] generated by the convective motion of charged, molten iron, far below the surface in Earth’s outer core” (NASA.gov), becomes highly energized. This leads to an intensified ring current, which is an electric current that flows around the Earth that is created by the solar wind (Ioannis A. Daglis *et al.*). When the ring current reaches a certain intensity level (quantified by the *Dst* index), the activity is considered a geomagnetic storm. Geomagnetic storms are often caused by “extreme conditions in the solar wind,” (Hutchinson, Wright, Milan) like coronal mass ejections (large-scale expulsions of plasma from the Sun) and co-rotating interaction regions (caused by high speed solar winds colliding with slower solar wind) (noaa.gov). Geomagnetic storms do not necessarily have a major impact on life on Earth, but intense geomagnetic storms—especially those caused by coronal mass ejections—can cause disturbances and permanent damage to telecommunication and navigation satellites, telecommunication cables, and power grids (Ioannis A. Daglis *et al.*). Thus, geomagnetic storms have the potential to damage infrastructure and learning more about them is valuable to the stability of society. Past research has analyzed geomagnetic storms to better understand the phenomenon and provide information for future research. However, the research I discovered was for the last solar cycle, which ended in 2011. Since solar cycles last 11 years, the sun is nearing the end of another solar cycle. Therefore, now is an excellent time to revisit this type of study but with data from the current solar cycle. I am researching geomagnetic storms because I want to answer this question: “What can be learned from the most recent data collected on geomagnetic storms and how can we prevent catastrophe to infrastructure if intense geomagnetic storms occur in the future?”

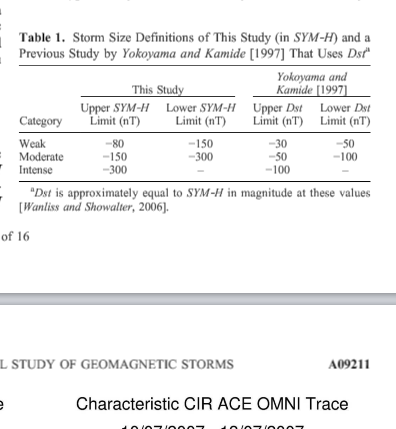
*Background/Related Work and Motivation*

The main foundational work I am using to base my own research on is “Geomagnetic storms over the last solar cycle: A superposed epoch analysis” by J. A. Hutchinson, D. M. Wright, and S. E. Milan. They conducted a thorough analysis of geomagnetic storms and separated them into three different categories: weak, moderate, and intense. To divide the storms into these categories, the researchers used the storms’ “characteristic SYM-H evolution,” an index used to measure the intensity of the ring current during a geomagnetic storm (similar to the Dst index). While quite thorough, it was published in 2011 on the solar cycle which had just ended. The current solar cycle is ending in approximately a year (it began in December of 2008), and data collection has only improved since 2011. Thus, I was motivated by the fact that now is a great time to begin research on the current solar cycle using the abundance of data collected over the past cycle. I will use this study as a model from which to derive my methods when I do my research.

Another foundational work I used to arrive at my proposal is “What is a geomagnetic storm?” by W.D. Gonzalez, J. A. Joselyn, Y. Kamide, H. W. Kroehl, G. Rostoker, B. T. Tsurutani, and V. M. Vasyliunas. This paper opened the way for me to come to an understanding of geomagnetic storms conceptually, and also discussed the relevance of geomagnetic storms as they pertain to their potential to damage infrastructure. The work has been cited over 960 times (on the database I accessed alone), which shows its relevance and importance to the field of magnetospheric physics. This paper introduced me to much of the information describing geomagnetic storms that I used in my introduction, so it played an especially crucial role in the development of my proposal. It also made clear to me the ability of geomagnetic storms to cause damage to infrastructure, which pushed me towards my overall question: “What can be learned from the most recent data collected on geomagnetic storms and how can we prevent catastrophe to infrastructure if intense geomagnetic storms occur in the future?”

*Methods*

First and foremost, I will need to acquire access to data pertaining to activity in the Earth’s magnetosphere from the last ten years. To accomplish this, I’ll use the National Oceanic and Atmospheric Association website to access geomagnetic storm data from the last solar cycle. Then, I will identify which periods of time count as geomagnetic storms and not simply a period of increased activity. To do this, I will use the same scale used by Hutchinson *et al.*



(The scale used in the Hutchinson *et al.* study)

Next, like Hutchinson *et al.*, I can identify what events cause these storms to occur, with the expectation that coronal mass ejections (CMEs) and co-rotating interaction regions (CIRs) are the culprits. I can ensure this is the case by matching up the occurrence of CMEs and CIRs to the occurrence of geomagnetic storms using data collected recording CME and CIR traces. The researchers in the study I am referencing found average durations of individual storm phases (categorized as initial phase, main phase, and recovery phase) and then adjusted the actual durations to the average durations. This “ensure[d] common points in the storm progression were superposed” (Hutchinson *et al.*). Essentially, this choice allowed the researchers to discover patterns in the time elapsed between each phase of a geomagnetic storm. In my research, I can use this method to display the difference between recent storms and the storms analyzed in this study. I will create a visual out of this data with emphasis on the frequency and intensity of storms, which will allow me to compare the activity of this solar cycle with the last one, and thus determine if worsening storms should provoke increased precautions to protect infrastructure.

In addition to mirroring the methodology of a past study with recent data, I will read thoroughly on the current risks of geomagnetic storms—partially through governmental sources (The National Science and Technology Counsel being one such source) and partially from other third-party sources—and preventative measures that can be taken and will present these as part of my final product.

*Expected Results*

My final paper will include an in-depth write-up of all the information I have garnered through my analysis of these recent storms, which will culminate in a visual representation of the changes from last solar cycle to this one. My paper will also include a section on what precautions can be taken in the event of an extreme geomagnetic storm that affects infrastructure.

*Conclusion*

Geomagnetic storms are intervals of sufficiently intense activity in the Earth’s magnetosphere. These storms have the potential to damage telecommunications cables and power grids, which means they are not a threat to be taken lightly. Basing my work on a previously conducted study by Hutchinson *et. al,* I plan to emulate their methods to conduct a similar study to answer the question “What can be learned from the most recent data collected on geomagnetic storms and how can we prevent catastrophe to infrastructure if intense geomagnetic storms occur in the future?” In addition to characterizing and separating storms as done in the Hutchinson study, I will create a visual based on the data showing the change in intensity and in frequency of geomagnetic storms from the past solar cycle to this one. This will help me understand the need for precautions for infrastructure. Then, I will research different methods towards achieving the goal of protecting infrastructure. In the end, I will produce a paper that contains in depth analysis of the geomagnetic storms of the current solar cycle and contains a visual emphasizing the change in intensity and frequency of storms from the past cycle to this one. The paper will also include ways to prevent damage to infrastructure should geomagnetic storm intensity reach dangerous levels.

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*Budget*

This research will not require me to travel, nor will I need to pay for access to any data. So, the only true cost will be paying me for my time spent researching, analyzing data, and creating a paper. My research will begin with acquiring data from the NOAA, followed by employing the same techniques as Hutchinson *et. al* in their study. I will estimate that this process will take me 75 hours, and at $15 an hour, will require $1,125. Then, I will create a visual and perform further research to discover the best preventative methods. I will estimate that this process will take me 10 hours, requiring $150. Finally, I’ll create a paper and compile all of my results into it, which will take me 25 hours and cost $375. Therefore, the entire research process will require a grand total of $1,125 + $150 + $375 = $1,650.