# Seasonal Effects on Quiet Time Identification

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# 1 Abstract

The Earth's magnetosphere is a very dynamic body which is constantly changing. There has been a lot of research done that deals with the highly active events of the magnetosphere, such as Steady Magnetic Convection (SMC) and substorms. The goal of this project is to do the opposite. This project looks at the more quiet times that occur in order to define what it takes to be inactive. We also hope to find out whether or not there is a seasonal effect in the number of SMCs and substorms that occur as well. This project uses high latitude magnetometer data in order to analyze the vales of AU, AL, and AE, which are indices relating to magnetospheric activity. This data was organized, analyzed, and plotted with python to allow for easier observations.

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## 2 Introduction

This project was indented to analyze activity levels in Earths magnetosphere and find a more concrete understanding on what it means for the magnetosphere to be inactive. The ionosphere has slightly higher levels of activity in the summer than in the winter, which would lead to the idea of having a seasonal trend that would have to be implemented in cutoff values. Through the use of high latitude magnetometer data, we can look at and analyze years of data to attempt to see what the trends look like. Is it possible to have a flat cutoff value with this fluctuation in activity, or is a curve necessary to compensate for this? One researcher, McWilliams, makes an assumption about what might happen with the inactive times based on what happens with the active times. She states that since the number of SMC's and substorms occur at about the same rate regardless of the season, the inverse should also be true. This means that in order to identify quite times, there would need to be a curved cutoff value line. She made a line that she used to identify quiet times based on some of the data that she found. The formula for her cutoff values is as follows:

$$AE[nT] \geq 90 + 110cos^5\left(\frac{(x-173)}{365}\pi\right) \tag{1}$$

This was her cutoff for active times, so the opposite will be used in my research. There is a bit of controversy in whether or not this is what needs to be done to identify quiet times or not. My study looked into different flat cutoff values, not a curved and there will be a comparison of results at the end.

## 3 Methodology

1. Used Python to analyze magnetometer data
2. Focus on the indices AE, AU, and AL
3. Tallied, averaged, binned, and plotted data over multiple years
4. Manipulated plots for easier visualization of data

The way my graphs were created was by using python to parse through massive data files and compare the index in question to a certain cutoff value. If an index met the cutoff, I would increase a counter. I would average these counts over the course of each day for each year of data that I had (1997-2009). I averaged the data into 20 day bins to decrease the amount of clutter on the graphs.

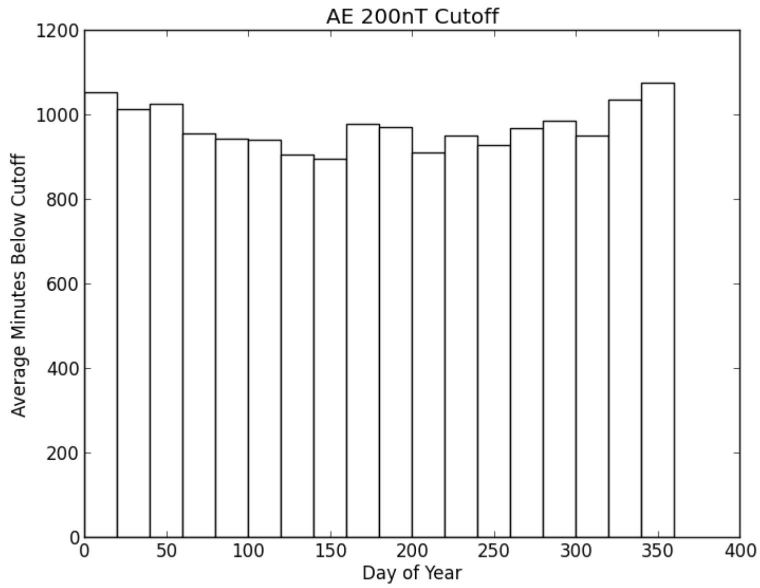


Figure 1: Plot of AE when minute values were less than 200nT

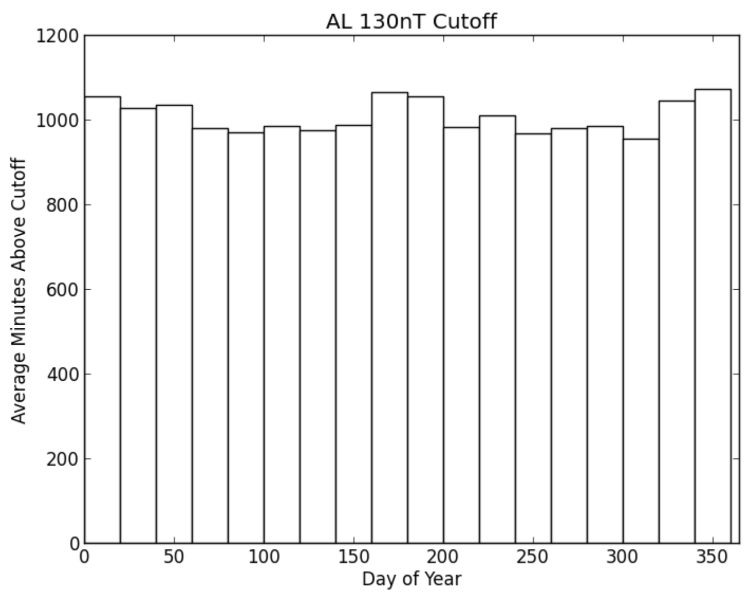


Figure 2: Plot of AL when minute values were greater than -130nT

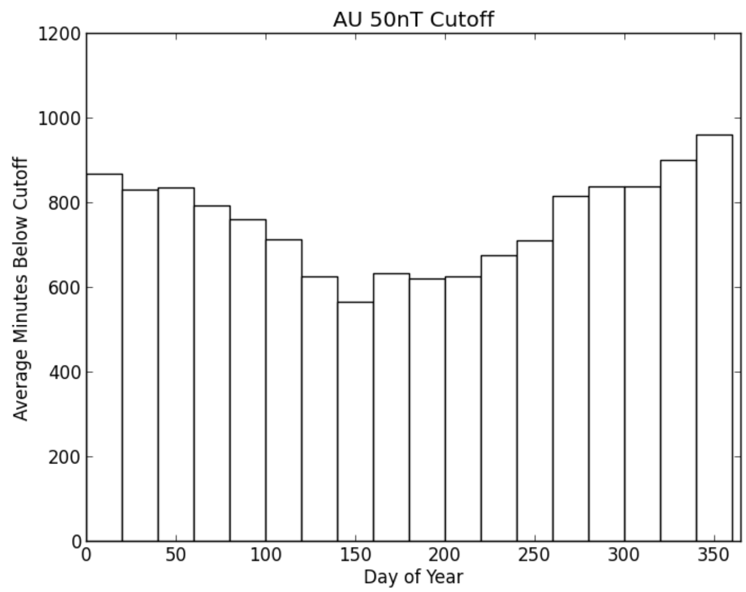


Figure 3: Plot of AU when minute values were less than 50nT

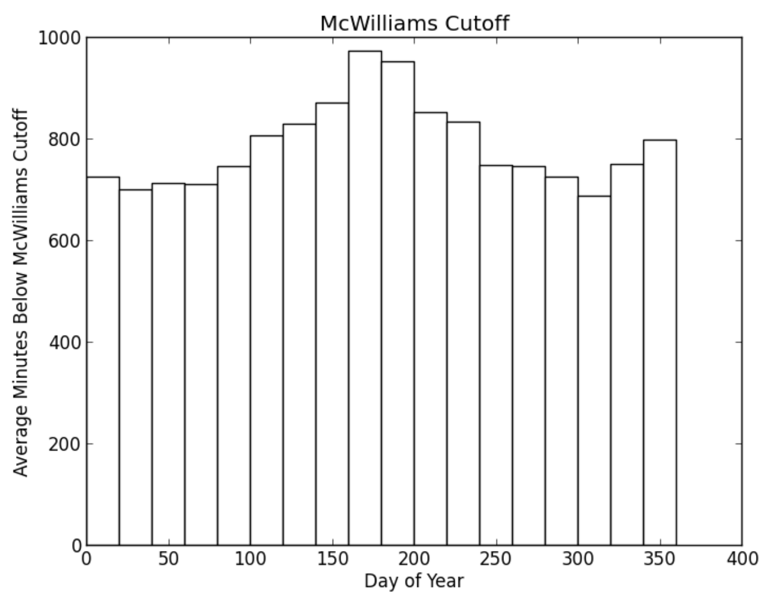


Figure 4: Plot of AE when minute values were less than the McWilliams cutoff curve

## 4 Discussion

In the beginning of the semester we were looking at the raw level of the activity. Once this data was plotted and analyzed further however, we decided that this method wasnt exactly what we were looking for. This data showed how active the inactive times were rather than purely analyzing if they were inactive or not. What we decided to do at this point was to find the inactive times based on a certain cutoff and make a sum of all the points that were fitting the cutoff. Once this data was gathered and plotted, it was much more showing to what we wanted. The plots seem to be geared towards what we need. For the indices AE and AU, the cutoff would serve as the high point for the data but for AL, it will be the low point. This is because the AL index is more active the further negative the values go. Basically, when the absolute value of the index is closes to zero, it will be more quiet. AL is just different than the others in the fact that it has an negative value for activity measuring.

In *Figure 1* I plotted the average number of minutes each day where AE fit a flat cutoff value of less than 200nT. There does not seem to be that much seasonal variation in this data, it is fairly constant throughout the entire year. In *Figure 2*, the plot shows the data gathered for the index AL that was greater than -130nT. Again, there is not too much seasonal variation in this index either. *Figure 3*, shows the plot of AU that met a cutoff of less than 50nT. This index is the first one that we see with seasonal variation. This is most likely due to the fact that AU is more closely tied to activity in the ionosphere. Finally, in *Figure 4* I used the cutoff that McWilliiams used in her research (equation (1)). This graph also seems to show seasonal variation in the AE index.

Since the whole point of this study was to find a cutoff value that could be used to identify what exactly a quiet time is, I compared the results that I got from *Figure 1* and *Figure 4*. This was to see what kinds of differences were found between the two plots. Both plots use the same index to identify quiet time, but in looking at the two, they look very different. When a flat cutoff is imposed on the data, there is little to no seasonal variation in AE. However, when a curved cutoff is placed to compensate for the McWilliams assumption mentioned earlier, there is a big difference. The difference is not only in how much seasonal variation there is, but also on the numbers themselves. The flat cutoff averages range from about 1050 to 950 per day, while the Mcwilliams cutoff shows

## 5 Conclusions

While we were unable to give an absolute method to identify what exactly a quiet time is, there were a lot of things that came to the table during the process of this project. First off, I was able to recreate some results that have been found by other researchers. The big similar result was that I was able to see a seasonal effect in the AU index and not in the AL index. Another thing that we saw is that the seasonal variation in AE seems to be very biased on what kind of cutoff we used. When looking at AE with a flat cutoff, not only are the frequency of inactive times greater, but the seasonal effects are much less as compared to the curved cutoff that McWilliams used. The questions now are:

1. Why does AU have so much seasonal variation and AL does not?
2. Is the McWilliams assumption valid?
3. What is the best way to identify truly quiet times?

## 6 Future Work

If I was to continue this research, I would want to look into the 3 questions left unanswered above. We know that AU is more closely linked to the ionosphere than AL so this could be the cause of the change in seasonal variation, but is it the only reason? From my study, I cannot prove the McWilliams assumption either correct of incorrect. It could still be valid to say that since the number of SMCs and substorms occur at the same rate regardless of season, the inverse will hold for the quiet times. We just don't know. Overall, getting a clear cut definition of what it means to be quiet would be a good thing to have when identifying possible SMCs and substorms.

## 7 Personal "Take Aways"

When going into this project, I had very little experience with coding and no experience dealing with large data sets. This project gave me a first hand look at what it takes to analyze data that I really didn't get in a course at CNU. Not only that, but I got to get an experience in my undergraduate career of what exactly the scientific process is all about. The saying "research is what you do when you have no idea what you're doing" really means something to me now. Although we might not have known exactly what we were going to find, we had to think of different ways to look at the data that we had. There was a whole branch of analysis that I did that ended proving a null result that I did not include in the paper because of the results. I also got to get a great understanding of solar wind, plasma, and magnetic field interactions.

## 8 References