Iris Yan
Mentor: Dr. Aiyou Chen

Developing a Machine Learning Algorithm to Accurately Predict Geomagnetic Storms

Large scale geomagnetic storms can cause severe damage to satellites, power grids, and radio communication. They occur when solar wind shock waves or clouds of magnetic waves disrupt the magnetosphere, affecting regions worldwide. Minor storms usually occur 1700 times in 1 solar cycle (11 years), and extreme storms usually occur 4 times in 1 solar cycle. Space weather data, like solar wind conditions, can be used to predict storms. Currently, deep learning and probabilistic models have been created for geomagnetic storm prediction, but they have been less accurate on early predictions. The purpose of this project is to develop a machine learning algorithm to predict geomagnetic storms earlier and more accurately. Past solar activity data from Space Weather Prediction Center and Space Physics Data Facility will be used in training and testing the algorithm. First, the algorithm will be created using the R program to learn patterns that occur before a geomagnetic storm, like solar wind speed or other solar conditions. Using the past data, the algorithm will be able to predict future Kp indices, or the magnitude of future geomagnetic activity. Feature extraction and downsampling will then be applied to improve the accuracy. The algorithm will be tested with past data from German Research Centre for Geosciences (GFZ), and the accuracy will be determined by comparing the Kp index predictions of the algorithm with the actual Kp indices from past geomagnetic storm data. Statistical analysis, such as a t-test, will be performed to find the statistical significance of the results. Constraints for this project are the amount of data available and the amount of time to complete this project. The goal of this project is to make progress toward improving earlier geomagnetic storm predictions. Predicting geomagnetic storms earlier and more accurately will allow people to prepare beforehand and greatly decrease the amount of damage caused to satellites, power grids, and other electronics.

Bibliography

"Geomagnetic Storms." *Geomagnetic Storms | NOAA / NWS Space Weather Prediction Center*, https://www.swpc.noaa.gov/phenomena/geomagnetic-storms.

"Kp Index." *The Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences*, https://www.gfz-potsdam.de/en/kp-index/.

"Real Time Solar Wind." *Real Time Solar Wind | NOAA / NWS Space Weather Prediction Center*, https://www.swpc.noaa.gov/products/real-time-solar-wind.

"SPDF - Omniweb Service." *NASA*, NASA, https://omniweb.gsfc.nasa.gov/index.html.

Chapman, S. C., and R. B. Horne. "Using the aa Index Over the Last 14 Solar Cycles to Characterize Extreme Geomagnetic Activity." Geophysical Research Letters, https://doi.org/10.1029/2019GL086524. Accessed 26 Oct. 2021.

"Geomagnetic Storms." Space Weather Prediction Center, www.swpc.noaa.gov/phenomena/geomagnetic-storms. Accessed 26 Oct. 2021.

Podladchikova, T. V., and A. A. Petrukovich. "Extended geomagnetic storm forecast ahead of available solar wind measurements." Space Weather, https://doi.org/10.1029/2012SW000786. Accessed 26 Oct. 2021.

Wu, Jian Guo, and Henrik Lundstedt. "Prediction of geomagnetic storms from solar wind data using Elman Recurrent Neural Networks." Geophysical Research Letters, https://doi.org/10.1029/96GL00259. Accessed 26 Oct. 2021. Abstract.