Space Weather Detection Model

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Abstract

Our research topic is regarding the Space Weather detection model. As data scientists, it is of the utmost importance that we are able to draw conclusions from our data that is taken from variables in a real-world environment.

As data scientists we make hypotheses' based on our observations of variables occurring in the real world. The current problem we are facing as Data scientists is regarding the problem of natural phenomena affecting our ability as data scientists to accurately detect the communication between technological devices that globally communicate with one another. The problem that arises for the effective communications of these global technological devices to interact with one another are the natural phenomena like solar flares and electromagnetic storms which we as data scientists are unable to accurately predict worldwide, which can be a very huge problem.

This is a huge problem as communication between for example a GPS and a respective satellite is disrupted by wave structured variants in ionospheric electron content and this variation will cause propagation, which is a problem and heavily affects human life at its core in today's data driven world in which millions depend on the accuracy and functionality of a GPS daily for work and personal life. Our approach to solve this problem is through creating a regression model which would analyze the data acquired in the past to give future predictions of space weather. We applied the pattern recognition and logistic regression to determine the presence of Solar radiation. We indeed discovered that there is solar radiation occurring within a specific time period within our speed and density data calculations. We created a detection model, focusing on speed and density of our data, which acquired the current data and compared it with the past data models to verify our results. Our results display the presence of solar radiation in the ionosphere.

Introduction

With satellite communication becoming popular and people trying to commercialize space/earth's orbit expeditions, space weather has become a key focus. This leads to the importance of space weather studies, which collects data on all the Sun and its events. With the exponentially expanding technological focus towards global communications, there has been an increasing focus to study and understand the environment in which these communications propagate. These communications can be adversely affected by a multitude of phenomena like solar flares and electromagnetic storms, which we are currently unable to predict accurately.

The few instruments worldwide that can detect and study these phenomena don't have the necessary coverage to help further our understanding. This report describes the study process, requirements, and relevance of space weather observing systems used for operations, and a summary of key findings. One new potential instrument that has been proposed by Dr. Nathaniel Frissell of the University of Scranton is using Amateur ham radios. Case studies have shown that ham radio data can accurately detect one such phenomenon called Traveling Ionospheric Disturbances(TID), which are wave structured variations in ionospheric electron content. Communications from GPS, radio, and satellite are affected by the electron content and therefore any variation will change propagation. The earth is surrounded by complicated patterns of magnetic fields that are around the earth to protect from harmful effects of outer space. Earth's weather is immediately affected by any unusual occurrence in Space weather.

Space weather can enter the planet's magnetic field and the atmosphere which affects the earth depending on what the sun storms are like and how they flow. Space weather can cause a lot of damage if the storm gets too severe. Cell-phone communications can be disrupted and can cause a power black-out in a large area of the world due to the severe weather. Not only that but space weather's long-term effects on the earth's atmosphere can cause the planet to be uninhabitable for all forms of life. The result for our project shows new models that address the broad range of space weather's prediction requirements from the Sun to the Earth.

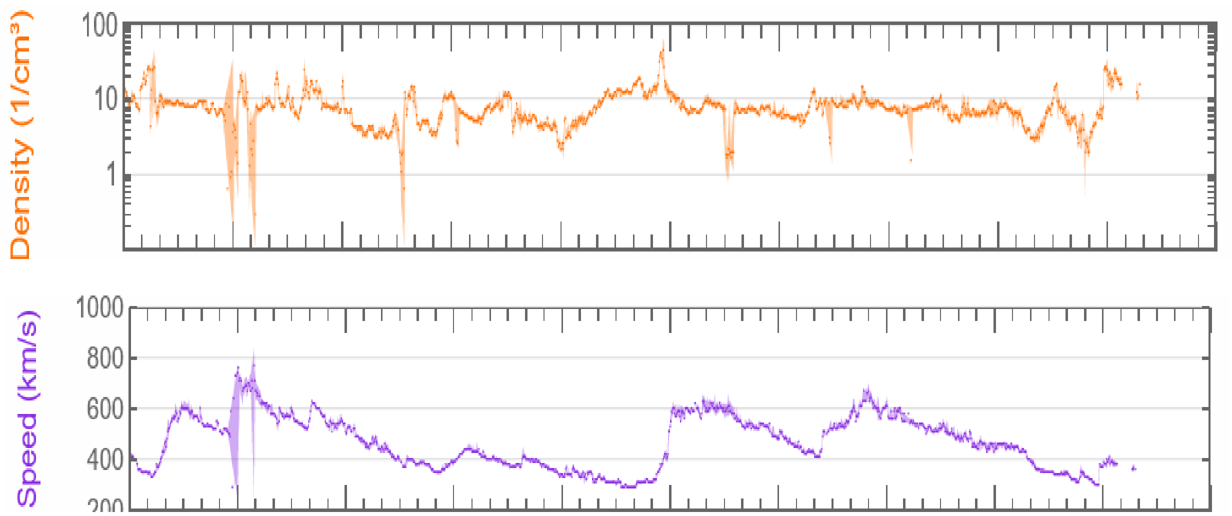
Related work

Space Weather Prediction Center (National Oceanic and Atmospheric Administration) analyzes different readings like Total Electron Content (TEC), Maximum Usable Frequency (MUF), Total Electron Content (TEC) Anomaly, Maximum Usable Frequency (MUF) Anomaly to Provide Current Space Weather Conditions. One of the key elements of Space weather is the Prediction of Solar Winds. SWPC analyzes Radiation IMF Polarity at the earth for a period of 24 – 25 days to get 3-day Advanced Predictions of solar wind on earth. Another key element is a prediction of Interplanetary Magnetic Field (IMF) Polarity at Earth. SWPC analyzes Solar Wind Speed at Earth for a period of 24-25 days to get 3-Day Advanced Predictions and Satellite Observations.

The National Weather Service (National Oceanic and Atmospheric Administration) has developed a Breakthrough computer model to provide space weather forecasts to give more targeted warnings. The Whole Atmosphere Model and Ionosphere Plasmasphere Electrodynamic Model (WAM-IPE Model) are used as a forecasting tool by SWPC. It is based on the fact how Earth's upper atmosphere will respond to change in solar and geomagnetic conditions. Total Electron Content and Maximum Usable Frequency are analyzed for total and accurate predictions according to this model. The approach which we will be using for the prediction will be to analyze solar radiation(wind) activity and its effects for a period of time to create a prediction model.

Data

For this report, we will be working on the data we acquired from the National Oceanic and Atmospheric Administration. We are able to get real-time Solar wind data for a spacecraft which is located in the L1 lagrange point and is received and tracked by the tracking station. We will use the solar wind Density on earth from 11/1 to 11/15. This will enable us to gather information about the changing solar density speed in a period of 24 days and how wind speed affects the space weather. We will also be using the Interplanetary Magnetic Field (IMF) for the same time period as a reference to solar winds. The IMF is based on the change in solar winds on Earth. Our data majorly constitutes numerical reading of solar density (1/cm^3) for a span of 27 days. We can convert this numerical data in a graph format with x-axis as time and y-axis as the solar density. Along with this the second type of data that we would be using is the speed of solar winds propagating towards the earth's surface.



The raw data we have consists of solar wind density and solar wind speed for every hour between the time frame of 1 November to 20 November. We will be converting our numerical data into a line graph where y represents the Solar density and Solar Speed respectively and x represents the time. We have studied an instrument that has the ability to better accurately predict these natural phenomena.

This instrument was proposed by Dr. Nathaniel Frissell of the University of Scranton using Amateur ham radios. Case studies have shown that ham radio data can accurately detect one such phenomena called Traveling Ionospheric Disturbances(TID), which we have explained how this phenomena can affect the communication of global technological devices between a GPS and a respective satellite. We studied data from WSPRNet and the RBN. We were able to determine key results by using algorithms that were based on classification.

Methods

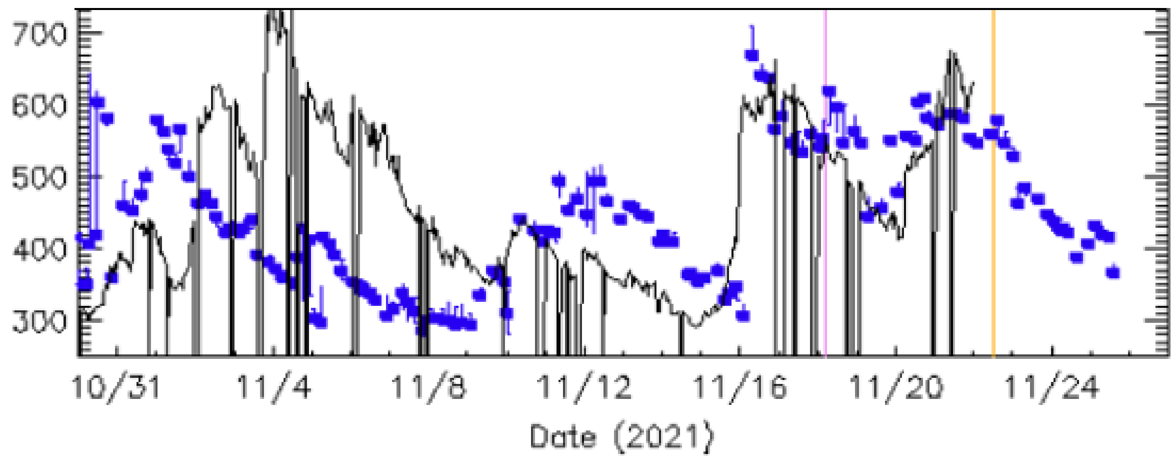
The main problem we are focusing on in this report is that we can use the data we acquired in the past to make a predictive model which will predict the solar radiation levels on earth and how accurate this model is in comparison with the real data. We will be creating a graphical representation of the solar radiations level by using the data which we acquired from the Space Weather Prediction Centre. You can find the total raw data in supplementary material. The total data consists of temperature, speed, solar radiation density, solar flux axis and maximum amplitude of the radiation. For the ease of analysis, we choose to develop graphical representation of solar radiation density and speed as shown below.

Analysis of speed and density of solar radiation should be the right approach as solar radiations are made up of X-rays which affect high frequency radio waves used in satellite and telecommunication. Energetic radiation particles can cause electric failure in satellites. To ensure necessary preventive measures could be taken in advance, solar radiation predictions models are generated. To predict the amount of Solar radiation, we would be developing a regression model. We will be using Keras: Python deep learning API library to get a reference for our model. This will enable us in creating a model which will predict the solar radiation density and speed. Then we will be comparing our prediction with the original data for that time. This will enable us to compare our predictive model to the actual model. Please refer to the experiments part to get our predictions generated by the model.

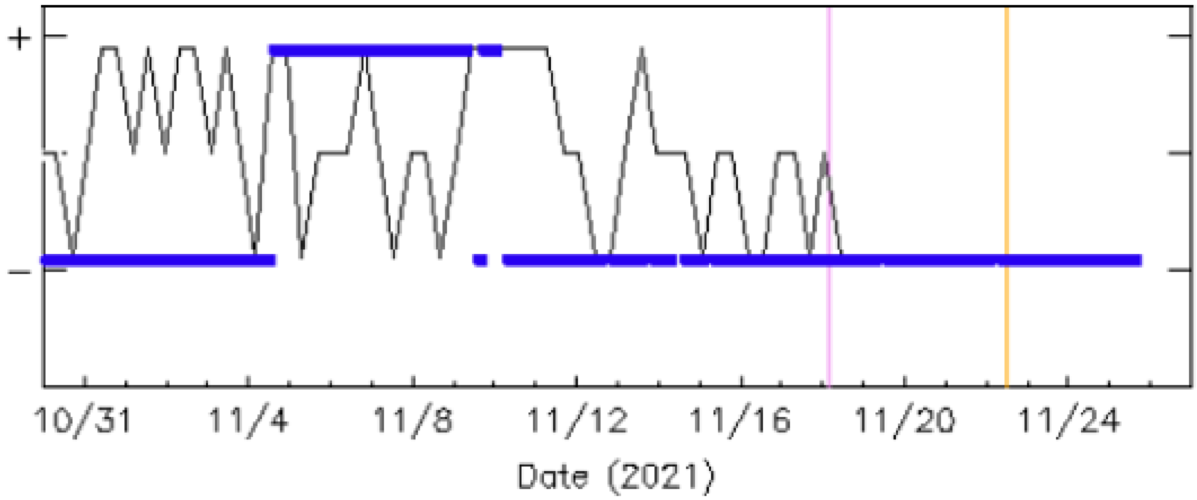
Experiments

For the experiment, we use linear regression to predict the speed and density of solar radiation we can expect. Linear regression is the linear modeling of the relationship between the dependent variable and the independent variable. To start the experiment, we first will be cleaning the data with the focus of only getting the solar radiation levels of different days. Once the data was clean, we used it in our linear regression model by plotting a line that fits our scatter plot the best.

Solar wind speed on Earth's orbit (Actual VS Predicted model)



Radial Polarity at Earth's Orbit (Actual VS Predictive model)



The scatter plot shows that the actual solar wind speed on Earth's orbit was further than what we predicted. The actual shows that the wind speed increased at first and decreased exponentially and then towards the end increased again while the prediction that we came up with was not so close in the beginning but towards the end, it aligns with the actual. We can see the blues dots (prediction) decrease and then at 11/12 it increases. By 11/16 our predictions are matching with the actual. The x-axis represents the speed in km while the y-axis represents the month and the date. From the scatterplot, it can be observed that the solar wind was high at the beginning of November but decreased toward the middle and exponentially increased toward the end of the month.

The second scatter plot shows the radical polarity at earth's orbit, the actual vs the prediction. The actual shows that the polarity increased and decreased throughout the month while the prediction that we came up with was not so close at all. We predict that the polarity will be decreased in the beginning and towards 11/6 it will increase till 11/10 where it will decrease again and stay the same. The x-axis represents the positive and negative polarity while the y-axis represents the month and the date. From the scatterplot, it can be observed that the radical polarity of the earth was increasing and decreasing toward the whole month.

Conclusion

In Conclusion, in this research project we applied the pattern recognition and logistic regression to determine the Solar radiation intensity pattern. We indeed learned and discovered that there is solar radiation occurring within a specific time period within our speed and density data calculations. As we are concluding this research, we have learned as a group that space weather is an ever changing phenomenon which is affected by many numerous factors. Space weather is affected by different times in years and state. Based on the data we had and the analysis that we made, we strongly feel that our predictions gave us a good outlook for solar wind speed. After doing the research, as a group we also strongly feel that a new application can be the telescopic analysis of the surface activity of the sun. This telescoping analysis will allow for a more accurate prediction and hence accurate data conclusions. As we know, on the sun there are countless number of explosions which occasionally happen on the sun and some of these explosions on the sun are more severe than others, leading to an increase in solar radiation.