SPACE WEATHER PREDICTION

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1. Problem Statement

As we are becoming more and more dependent on electricity to carry on with our everyday activities it has become imperative for us to predict the occurrence of solar storms and coronal mass ejections as they can interfere with the Earth's magnetic field resulting in drastic change of magnetosphere that generates powerful currents in the ionosphere. These currents are mirrored in the conducting earth as geomagnetic induced currents. Since the critical electrical infrastructure is grounded the induced currents can hamper power grids and communication networks. In this project we plan to explore and predict occurrences of solar storms based on 6 different indices. We consider decade long data sets that are publicly available. We plan to compare and evaluate our prediction against the leading model IRI [5].

2. Motivation

The threat of space weather has become an increased concern for government officials around the world. Powerful solar flares and coronal mass ejections (CMEs) can devastate the world's interconnected power grids, airline operations, satellites and communications networks. [2]

Different types of space weather can affect different technologies at Earth. Solar flares can produce strong x-rays that degrade or block high-frequency radio waves used for radio communication during events known as Radio Blackout Storms. Solar Energetic Particles (energetic protons) can penetrate satellite electronics and cause electrical failure. These energetic particles also block radio communications at high latitudes in during Solar Radiation Storms [6].

Coronal Mass Ejections (CMEs) can cause Geomagnetic Storms at Earth and induce extra currents in the ground that can degrade power grid operations.

Geomagnetic storms can also modify the signal from radio navigation systems (GPS and GNSS) causing degraded accuracy. These storms also produce the aurora. Space weather impacts people who depend on these technologies.

3. Data Description

We plan to predict the occurrence of solar storm based on the following features:

	Feature	Description
1.	AE index	A geomagnetic index of the auroral electrojet, which characterizes the maximum range of excursion (both positive and negative) from quiet levels.
2.	ap index	The Ap index is a measure of the general level of geomagnetic activity over the globe for a given (UT) day. The Ap-index provides a daily average level for geomagnetic activity. The Ap-index is thus a geomagnetic activity index where days with high levels of geomagnetic activity have a higher daily Ap-value.
3.	Dst index	A measure of variation in the geomagnetic field due to the equatorial ring current. It is computed from the H-components at approximately four near-equatorial stations at hourly intervals. At a given time, the Dst index is the average of variation over all longitudes. An index of -50 or deeper indicates a storm-level disturbance, and an index of -200 or deeper is associated with middle latitude aurorae.
4.	Kp index	Kp is a common index used to indicate the severity of the global magnetic disturbances in near-Earth space. Kp is an index based on the average of weighted K indices at 13 ground magnetic field observatories. The values of the Kp range from 0 (very quiet) to 9 (very disturbed) in 28 discrete steps, resulting in values of 0, 0+, 1-, 1, 1+, 2-, 2, 2+,...9.
5.	ASY	To describe the geomagnetic disturbance fields in mid-latitudes with high-time (i.e. 1 minute) resolution, a longitudinally asymmetric (ASY) disturbance index is introduced and derived for the H and D components, that is, for the components in the horizontal (dipole pole) direction H (ASY-H) and in the orthogonal (East-West) direction D (ASY-D).
6.	SYM	The geomagnetic disturbance fields in mid-latitudes with high-time (i.e. 1 minute) resolution, a

		longitudinally symmetric (SYM) disturbance index is introduced and derived for both H and D components, that is, for the components in the horizontal (dipole pole) direction H (SYM-H) and in the orthogonal (East-West) direction D (SYM-D).

4. Data Preprocessing

a. Missing data:
    - The percentage of missing data is usually small [3], but the following can be done based on what is more optimal:
        1. We can estimate this by using 3 day average or
        2. by taking a median over 27 days.
    - We will decide the actual approach as we explore our dataset further.

b. Normalization:
    - We do not plan to do any normalization at this point as it is important for us to preserve the data in its original form in order to make accurate predictions.

5. Analysis Approach

We plan to analyze the data in the following ways:

1. Each of the features described above have optimum ranges, we plan to exploit these ranges in order to predict the presence of a solar storm.
2. We can further classify the storms based on their onset times, seasonal variations like summer, winter, equinox and solstice, storm count per year, monthly variations.
3. This classification could be highly useful for studying the effects of storm on the total electron count in the ionosphere.
    a. Based on the classification done, we can find the total electron count during different seasons.
    b. We can also find the maxima and minima of the solar storm cycle depending on the number of storms per year.
    c. Classification based on the onset times helps in finding when the total electron count is affected the most like during sunset, sunrise or noon.
    d. We can also find out which regions of the country are affected the most, like the west coast, east coast etc.,
4. With the 6 indices as input, our model should be able to predict the occurrence of a storm.

6. Model Evaluation Plan

a. 10 fold cross-validation of data from 2001 - 2011
b. Results can be compared with IRI model.
c. Kappa between IRI and our model.

7. Data Source

- Dst - http://wdc.kugi.kyoto-u.ac.jp/dstdir/index.html
- Dst - http://www.aer.com/science-research/space/space-weather/space-weather-index
- Kp - https://www.spaceweatherlive.com/en/help/the-kp-index
- Kp - http://www.swpc.noaa.gov/products/planetary-k-index
- Sym index - http://wdc.kugi.kyoto-u.ac.jp/aeasy/

8. Reference

1. Glossary - http://www.swpc.noaa.gov/content/space-weather-glossary
2. http://www.accuweather.com/en/weather-news/noaa-issues-regional-forecasts-for-solar-storms-for-first-time-with-new-geospacial-model/60788980
3. http://geomag.usgs.gov/downloads/publications/LoveGannon1-minDst2011.pdf
4. http://onlinelibrary.wiley.com/doi/10.1029/2005JA011034/full
5. http://omniweb.gsfc.nasa.gov/vitmo/iri_vitmo.html
6. http://www.swpc.noaa.gov/impacts