Pathways to Coronal Magnetic Energy Storage and Release

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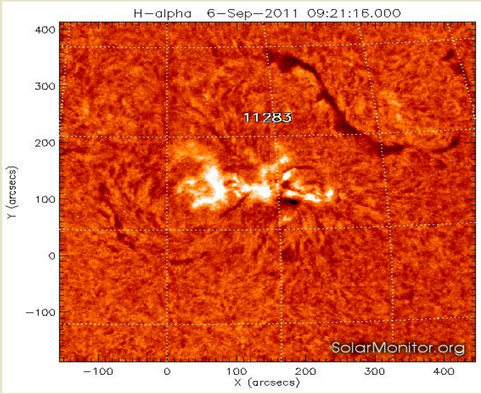
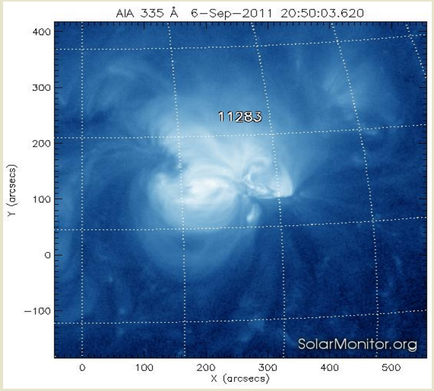


ABSTRACT:

At the extreme end of the variability spectrum, powerful events we call solar flares produce orders-of-magnitude increases in the shorter-wavelength luminosity output on millisecond timescales. Although it is generally accepted that solar flares occur through the release of energy stored in the coronal magnetic field above an active region it is not well understood how much of the stored energy will be released. When examined with a large sample size, solar flares generally follow a power-law distribution in size, although it should be noted that this may not be th e case for any individual active region. Such is the case for NOAA AR11283 (at central meridian on 2011.09.06). The current objective of the ongoing research is to use the magnetic energy stored with an individual current system of the region in tandem with the amount of energy released to compare to the region's flaring history. The investigation heavily focused on studying energy of the sub volume in the region rather than the whole region. In individual energy storage units it can be noted that while a small current accompanied by short field lines may not produce a great amount of energy, that is not necessarily the case when you lengthen the field line or increase the amount of current present. These different situations may produce different distributions of the amount of energy stored in that current system present.



METHODS OF ANALYSIS:

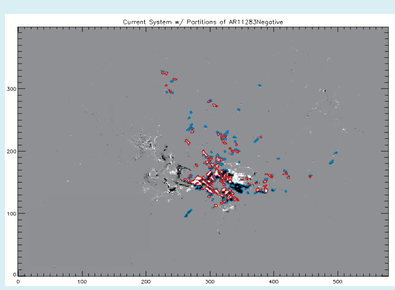
For the duration of this project, Non-Linear Force Free Field Modelling was relied on.
The Corona is in a magnetic field dominated region on the Sun (where the coronal magnetic field is not generally heavily influenced by the movement of plasma). The coronal field can then be considered "force free" because the only forces present at that moment are the balancing electromagnetic forces that the coronal field exerts by itself. In addition, field line tracing was a major part of energy estimates. For partition selection, you start by identifying current concentrations at the photosphere by using a downhill gradient method. Each point above the assigned threshold is assigned a local maxima value. Field line tracing is the propagation of current systems in the three-dimensional space of the chromosphere.

NOAA ACTIVE REGION 11283:

For this research the NOAA AR11283 was analyzed. This region was seen from September 02, 2011 to September 06, 2011. The specific images shown are based off of the observations from the HMI/SDO instrumentation. The investigated focused on NOAA AR11283 at central meridian on 2011.09.06.

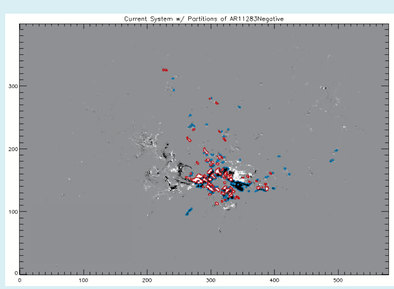
PARAMETER SELECTION:

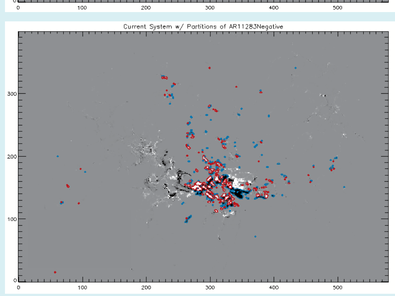
Note: The follow images are visualizations of the current systems on the region of analysis (noted by contours of colours red and blue)



J threshold

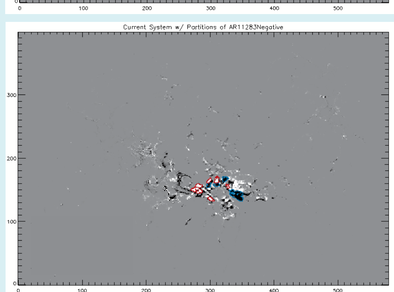
The level at which we observe from the photosphere. Larger thresholds reduce sun based noise.
Left: J Threshold is 200
Right: J Threshold is 400

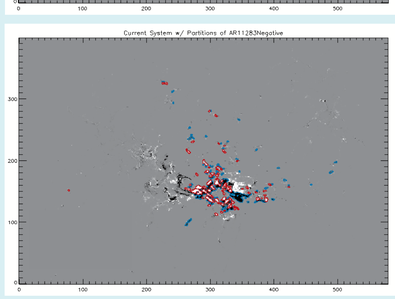




Minimum Size

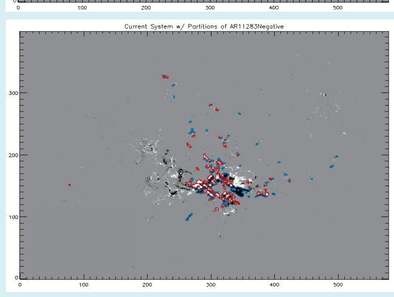
The smallest values of current we choose not to ignore. Helps reduce noise or unimportant current values.
Left: Minimum Size is 2e16
Right: Minimum Size is 2e20

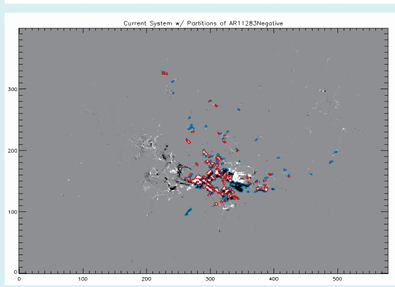




Saddle Point**

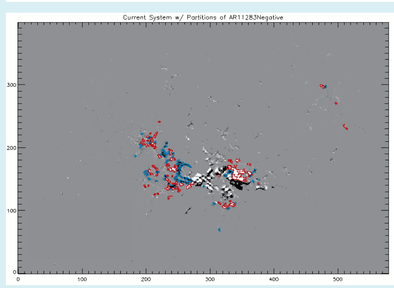
This signifies, if two peaks are near each other a saddle point would cause them to merge into one larger peak.
Left: Saddle Point of 500
Right: Saddle Point of 999



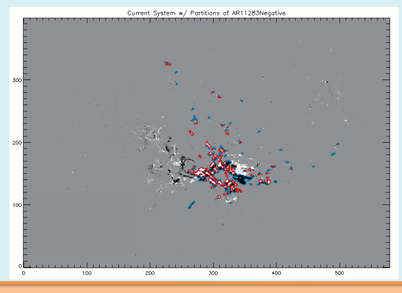


Polarity

This deals with the polarity of the magnetic field we are using to analysis the region. Using both would cause redundancies among the results.
Left: Negative Polarity
Right: Positive Polarity



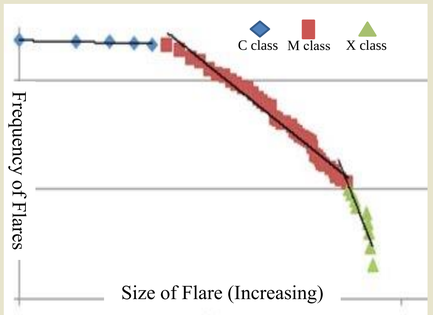
Final Selected Parameters shown on the image on the right:
J Threshold = 350
Saddle = 0
Minimum Size = 2e18
Polarity = Negative



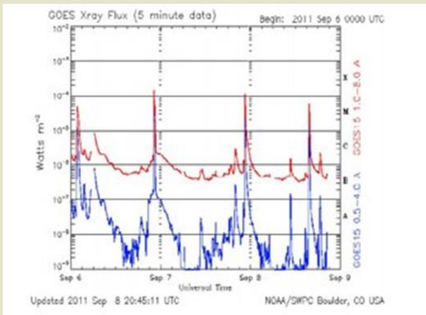
** Saddle Point has a quasi-maximum of 1000
It also can be noted that it is not expected for saddle point is supposed to behave the way such as shown in the images above

SOLAR FLARES:

Flares are classified by their peak in soft x-ray (0.1 to 0.8 nm band). Flares are firstly broken into 5 categories: A,B,C,M, and X. Typically class A and B flares are hard to distinguish from a mix of both the background noise from the Sun and the noise level of the instrument. Then, C class flares can be considered small. From there, M can be recognized as a medium size. Finally, the biggest flares are called class X flares.



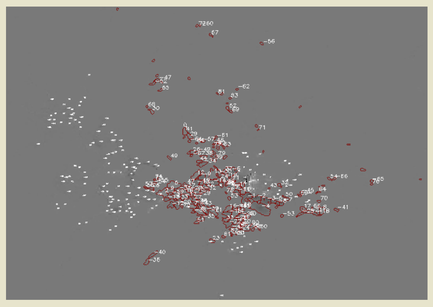
Over a large sample size we see a power law distribution. We can say that we expect most flares to be in the C and M classes while fewer in the X class.

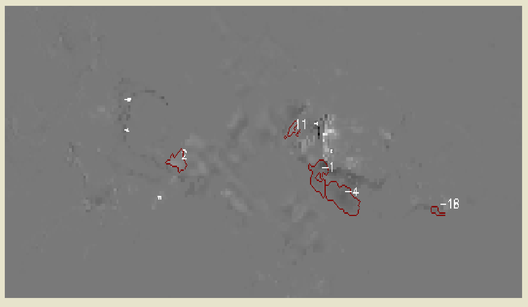


When we look at the distribution of flares in AR11283 on this date we do not see this power law. Particularly we see more class M and X flares than class C.

A NOVEL IDEA:

Typically, when analysis is done on an Active Region it is done over the entire region. For this project, the analysis was done on individual current systems instead. This allows for a more detailed investigation concerning the release of magnetic energy through a single reconnection event.
On the left below we see multiple current systems and it can be messy.
On the right we see fewer, stronger current systems we selected based off their properties.





MAGNETIC ENERGY:

Energy is stored in the magnetic field that is above the photosphere. This energy is thought to be released in reconnection events where the magnetic field goes from a complex state to a more simple one.

Current Systems:	Magnetic Energy (ergs):
N004	1.01E+30
N001	2.57E+29
P002	1.74E+29
P011	3.52E+28
N018	2.19E+28

On the left we see the top 5 current systems that produce the most amount of magnetic energy.
We note that -4 has the greatest footprint and the most energy.
We also note that + has a smaller footprint but a longer field line – with a lot of energy

FINAL STATEMENTS:

- This magnetic energy finding does prove a good point for the current hypothesis that if more energy is available for release (by solar flares) then the more active a region is.
- This project is an ongoing investigation on the NOAA Active Region 11283, to study the time-based evolution of the present current systems.

Data from the Helioseismic and Magnetic Imager on the Solar Dynamics Observatory was used to do analysis on the above-mentioned project.

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