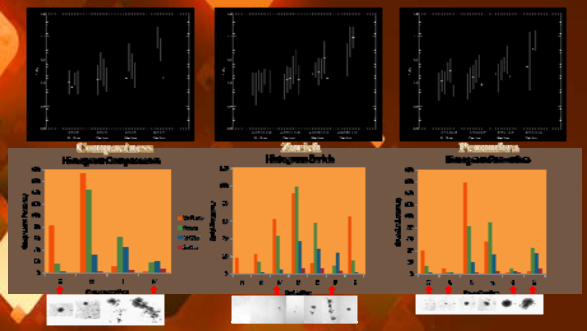
# Investigation of Active Region Properties for Solar Flare Forecasts

By: Feliciti Fredsti
Mentors: Alysha Reinard and Doug Biesecker
Site: NOAA

## Abstract:

It has become increasingly more important to be able to correctly forecast large solar flares because these events can destroy or interrupt important technology and harm astronauts. We looked at the relationships between different measurements and classifications of sunspots for patterns in the type of sunspot that produced a large flare. We selected active regions with complete data sets containing each of the measurements we wanted to compare; if an active region was missing a measurement, we removed it from the analysis. We also measured the distance between each active region and the nearest other active region on the disk. Once we obtained this information, we generated plots and histograms to look at the tendencies and frequencies of X-class, M-class, and C-class flares as compared to Non-flaring active regions. The trends were weak, but we found a correlation between various measures of active region complexity and flaring tendencies. Comparing this to the NHGV value (a parameter that uses subsurface motions to predict flare occurrence) we found that NHGV values tend to be higher for more complex and more compact active regions, even when the active regions produce a similar size flare.

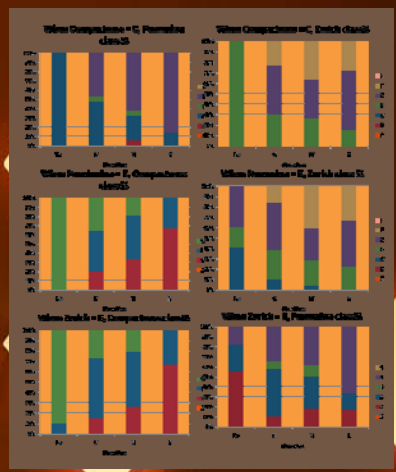



## Introduction:

In this investigation, we look more closely at the properties of active regions and compare flaring regions with similar non-flaring regions. The properties of the active regions that we investigated were compactness classification, penumbra classification, Zurich classification, Normalized Helicity Gradient Variance (NHGV), number of spots in the sunspot group, longitudinal extent, area of the sunspot group, and distance between the target active region and the next closest active region. In this investigation, we added the distance parameter in attempt to improve the forecasting of flare events. Especially with large scale flares, knowing which regions will produce flares helps us prepare for severe geomagnetic storms, solar radiation storms, and radio blackouts that could last for days damaging technology and presenting increased health risks for humans.

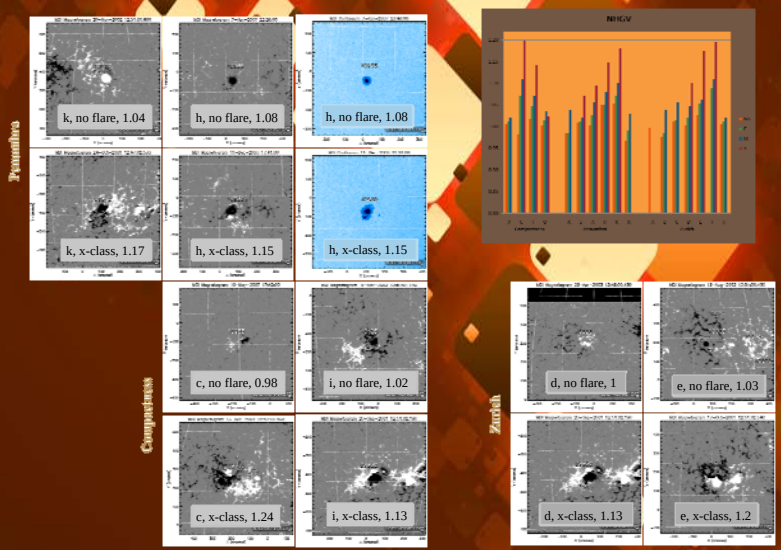
## Procedure:

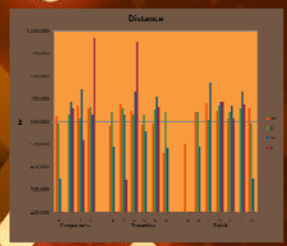
Within a previously writing IDL program that accounted for all parameters other than distance, we wrote a subroutine to extract the location of an active region and convert it into usable coordinates. We needed to convert the longitudinal coordinates into co-latitudes in order to use spherical geometry to calculate the distance between the two active regions. Then, we wrote another subroutine to measure the distance between the target active region and the next nearest active region using the converted coordinates. After incorporating the two subroutines, we were able to build plots to look for correlation patterns.



| Flare Class | Class Peak (W/m²) between 1 and 8 Angstroms | Pneumonic |
|---|---|---|
| X | $I \geq 10^{-4}$ | Xtreme |
| M | $10^{-5} \leq I < 10^{-4}$ | Mediocre |
| C | $10^{-6} \leq I < 10^{-5}$ | Cheesy |
| B | $I < 10^{-6}$ | Baby |

| Zurich (Z) | | Penumbra (P) | | Compactness (C) | |
|---|---|---|---|---|---|
| A | •small single sunspot or very small group<br>•same magnetic polarity<br>•no penumbra | X | • no penumbra | X | A single spot |
| B | •bipolar sunspot group<br>•no penumbra | R | • rudimentary | O | Open |
| C | •elongated bipolar sunspot group<br>•one sunspot must have penumbra<br>•penumbra longitudinal extent < 5° . | S | • small (<2.5 degrees north-south diameter)<br>• symmetric | I | Intermediate |
| D | •elongated bipolar sunspot group<br>•penumbra on both ends of the group<br>•penumbra longitudinal extent < 10° | A | • small (<2.5 degrees north-south diameter)<br>• asymmetric | C | Compact |
| E | •elongated bipolar sunspot group<br>•penumbra on both ends.<br>•penumbra longitudinal extent < 15° | H | • large (>2.5 degrees north-south diameter)<br>• symmetric | | |
| F | •elongated bipolar sunspot group<br>•penumbra on both ends.<br>•15°< penumbra longitudinal extent | K | • large (>2.5 degrees north-south diameter)<br>• asymmetric | | |
| H | •uni polar sunspot group<br>•with penumbra | | | | |




## Conclusion:

In conclusion, the more compact a sunspot group is the higher the probability of producing an x-class flare, sunspots with asymmetric penumbra are more likely to flare in the x-class then sunspots with symmetric or no penumbra. Elongated bipolar sunspot groups with penumbra at both ends are more likely to flare in the x-class than single spots, those without penumbra, and uni-polar sunspots. The distance parameter only slightly improved the accuracy but did not improve the false alarm rate. Studying the relationships between these parameters is still a work in progress.

http://ve4xm.caltech.edu/Bellan_plasma_page/laborato.htm 3 Aug. 2010
http://www.petermeadows.com/html/area.html 3 Aug. 2010
http://solar-center.stanford.edu/solar-images/magnetograms.html 3 Aug. 2010
http://spaceweather.com/glossary/filaments.html 3 Aug. 2010
http://solarmonitor.org/ 3 Aug. 2010
http://spaceweather.com/glossary/flareclasses.html 2 Aug. 2010
http://www.swpc.noaa.gov/info/glossary.html 2 Aug. 2010
http://www.swpc.noaa.gov/info/glossary.html 2 Aug. 2010
http://www.nso.edu/staff/apevtsov/www/gallery.html 2 Aug. 2010
http://solar.physics.montana.edu/magara/Research/Research_sig.html 2 Aug. 2010
http://euromet.meteo.fr/resources/ukmeteocal/verification/www/english/msg/ver_categ_forec_ex/ups3/ups3_ko1.htm 30 July 2010
http://www.cawcr.gov.au/projects/verification/ 30 July 2010
Reinard, A., J. Henthorn, R. Komm, and F. Hill. "Evidence that Temporal Changes in Solar Subsurface Helicity Precede Active Region Flaring." *The Astrophysical Journal Letters* 20 Feb. 2010: L121-L125. Print.