Using Hα Spectra and Imaging to Glimpse Precursors of Solar Flare Activity

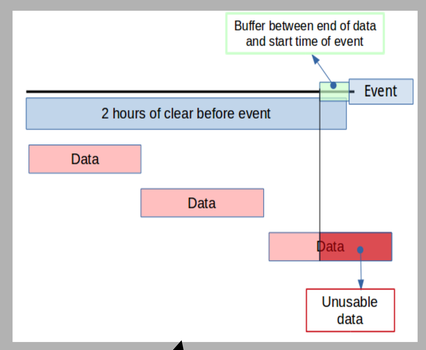
Alexandra Mannings, The University of Alabama, Tuscaloosa, Alabama
Mentor: KD Leka, NorthWest Research Associates, Boulder, Colorado

Introduction

The chromosphere, the transition layer between the photosphere and the corona, is thought to house small reconnection events before a flare event. Hα, being the defining chromospheric line, can show small changes that will indicate pre-flare signatures of excitement that are specific to pre-flare regions. We use data from the Mees Hα CCD Imaging Spectrograph, specifically a database of high-cadence Hα images and spectra of the sun's active regions. By sampling points in time that are directly before a flare or remain quiet for hours to days, we will be able to effectively compare the populations and how they change over time. The use of this data will enable us to look at activity before a flare that may differ in nature from a region that will remain quiet. Differentiating between the two will allow us to understand basic physical differences between the two populations and hence improve accuracy for flare prediction. High temporal cadence of the instrument allows us to show small intermittent changes that could possibly signify a developing flare. We will be sampling the data to measure characteristics such as line width, line depth, and Doppler shift – taking full advantage of the presence of the Hα well-sampled and widely sampled spectra (+/- 9Å). We parameterize these values and apply them to discriminant analysis to see if we can successfully describe pre-flare and pre-quiet chromospheric characteristics.

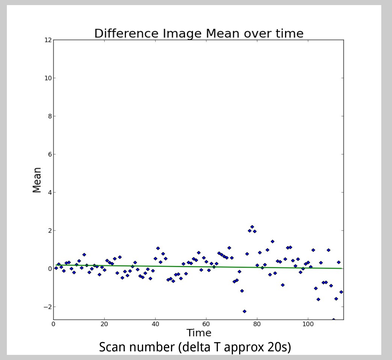
How we sample the data and things to consider:

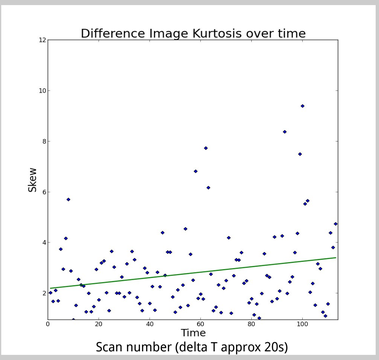
- Determine quiet vs event
- Event is defined by X-ray increase to B 5.0 level or greater (5 x 10^7 W m^2)
- Quiet event times are chosen within a 4 hour block of no activity
  - Compare what the sun is like normally to determine differences characterizing pre-flare activity
- Buffer ranges from 6-15 minutes.
- The two hours of clear occurs at least 30 minutes after a previous event (if one exists).
- We also account for multiple events that occur one after the other.
- Sample size: 30 minutes
  - Choose only one 30 minute slice during the 2 hour block (so as not to double count an event)



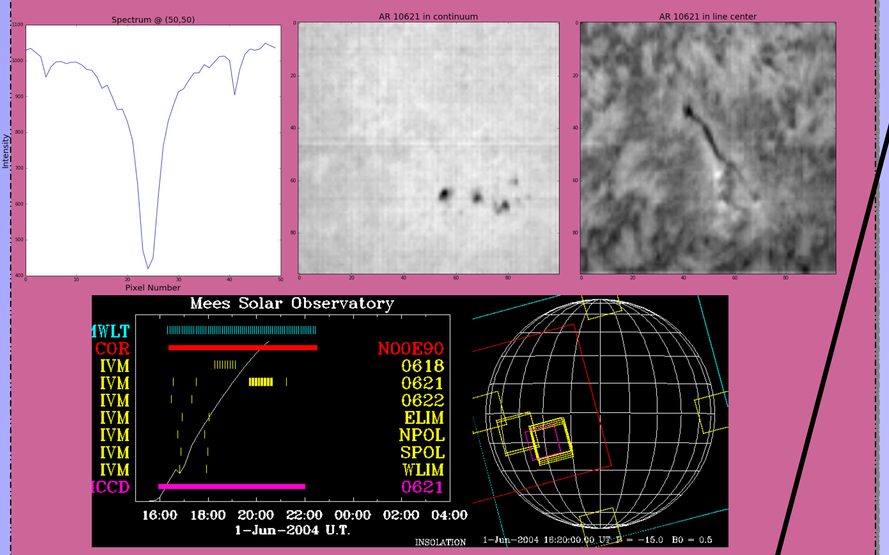
Parameters and Analysis

- Sampling the four dimensional data on the time dimension.
- Within the 30 minutes there are scans, and a value is determined at each scan. Therefore, we can show change over time.
- Below is an example of kurtosis and skew of the difference image distribution at every point in time. There is also a line fit to the data from which we can get a slope and an intercept (the two values used to represent the single value parameter).





What are we looking at?



MCCD spectroheliograms of NOAA AR 10621 on 1 June 2004 and a spectrum of the (50,50) position on the image. The deep line is Hα 656.28 nm. The shallow line to the right of it is an Fe line. The spectra spans +/- 9A from line center. Below those is a sample MSO log from 1 June 2004.

Basis of Parameters

- Line depth
- Line width
- Doppler shift
- Total area of sunspots in image
- Difference between images at line center
- Mu (cosine of observing angle)

The statistics

We complete higher order statistics including:

- Mean
- Standard deviation
- Skew
- Kurtosis

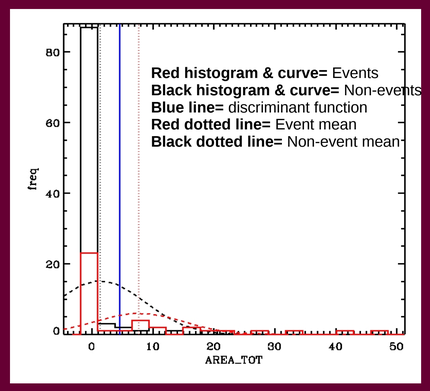
For each parameter that has a spatial distribution (line depth, line width, difference) we are able to do the higher order statistics on the spatial distribution to produce a single parameter tat each time sample.

For parameters like total area of sunspots and mu we only consider slope and intercept.

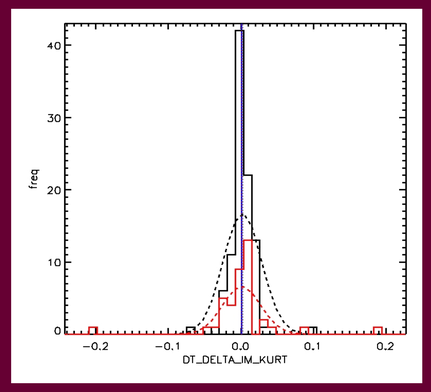
Discriminant Analysis

Here, we use a method of statistical analysis that uses the calculated parameters to try and differentiate between two different populations (event & non-event). Utilize higher order statistics to differentiate between the populations.

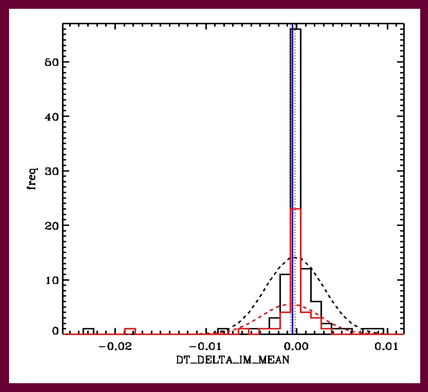
The goal is to correctly classify as many events/non-events as possible and to perform better than simply using the event climatology.



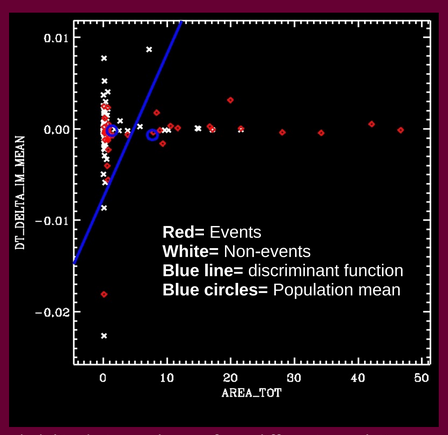
- probability that samples are from different populations: 1.- 0.00131054
- Appleman skill score (climatology): 0.153846



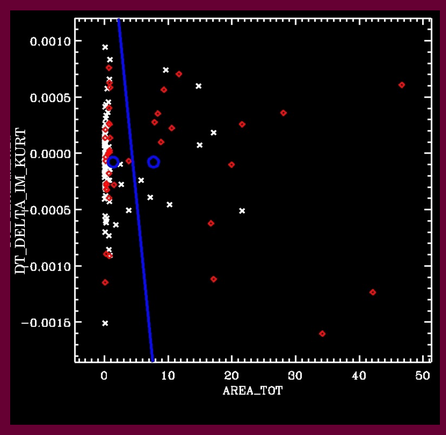
- probability that samples are from different populations: 1.- 0.909718
- Appleman skill score (climatology): -0.871795



- probability that samples are from different populations: 1.- 0.567863
- Appleman skill score (climatology): -0.256410



- probability that samples are from different populations: 1.- 0.000848370
- Appleman skill score (climatology): 0.153846



- probability that samples are from different populations: 1.- 0.00130940
- Appleman skill score (climatology): 0.153846

After analysis, it is seen that including DT_DELTA_IM_KURT or DT_DELTA_IM_MEAN in multi-variate analysis gives more information and allows for better characterization. Using either the first or fourth moments increased the rate of correct classification even though they were not strong candidates on their own- especially DT_DELTA_IM_KURT. The Appleman skill score remains constant, but we do see a slight push towards one in the probability that samples are from difference populations. AREA_TOT is a good parameter on its own, and its performance reinforces something that we already know about active regions (large total area means higher probability of flare activity) which is good.

Moving forward, we will incorporate more parameters and complete the discriminant analysis with all permutations of combinations of parameters to see which lead to the most accurate classification of the populations.

References: Des Jardins & Canfield 2003, ApJ, 598
Leka & Barnes 2003, ApJ, 595

This work was supported by the NSF REU grant 1157020 to the University of Colorado and NASA/HDEE grant NNX16AK34G.