Solar Irradiance, Image Restoration and Structure Identification

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Problem

- Solar Irradiance
  - Average incoming solar radiation
- How can this be modeled?
  - Varying Magnetic Features on the surface of the Sun will change how much radiation is observed
  - The 'quality' of an image could also change how solar features are quantified.
- In order to develop a rich model for solar irradiance, it is necessary to understand how solar images can be corrected for defects and how that correction will affect the way the solar features are identified.

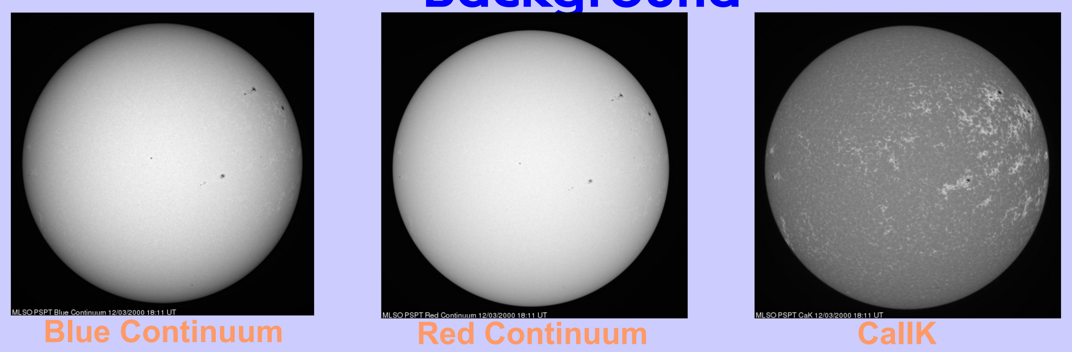
Abstract

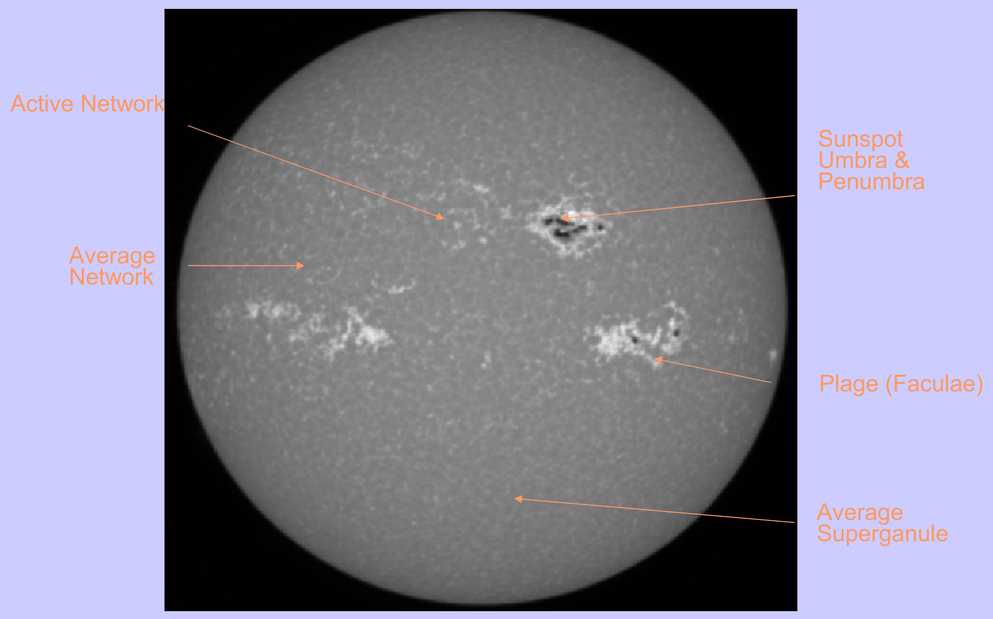
Image correction techniques were used on solar disk images form the Precision Solar Photometric Telescope (PSPT) to improve contrast and establish a better magnetic structure identification. In order to better understand how the restoration process affects identification, a "quality" is defined for a given image. That measure is then used to divide images into quality categories and to see how quality changes over a given observation day. An image from each category was run through the identification process, restoration process and then the identification again. The percentage of identified areas is noted for both the pre restoration and post restoration images and differences between the two were recorded. This procedure was repeated for each image over a given observation day. Results showed that average and active network areas would increase after restoration and active supergranule would decrease after restoration. Also, higher quality images tended to have higher average and active networks areas than lower quality images.

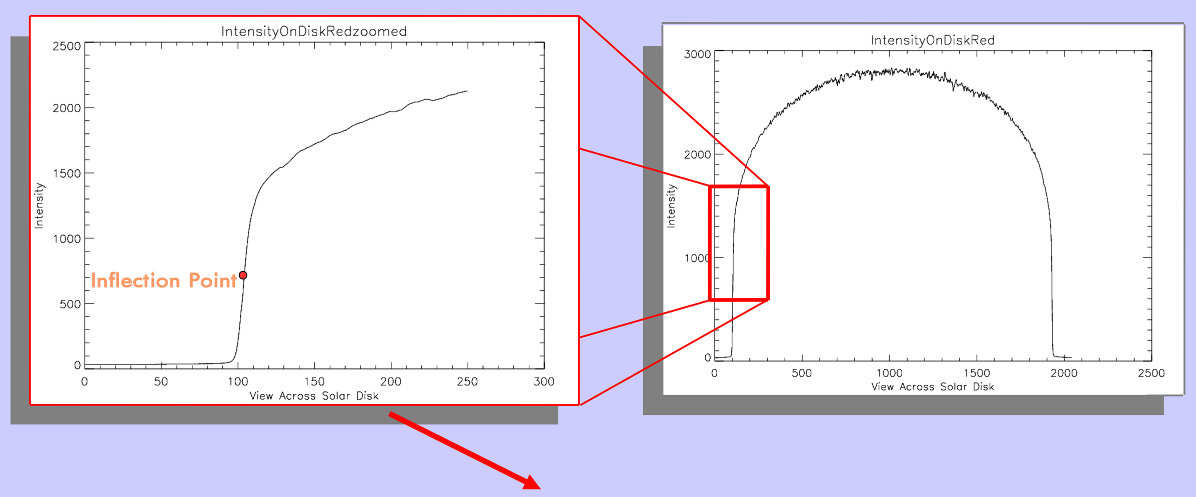
Procedure

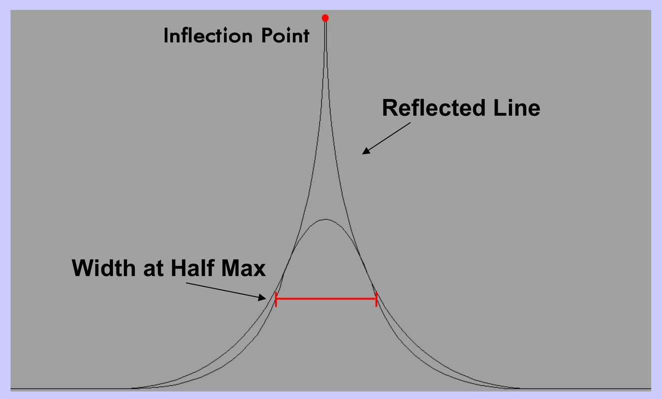
- Look at how Quality changes throughout a single observation day
  - Identify features on each image
  - Record the percent of area covered by each feature on each image
  - Observe how the areas change throughout an observation day as quality gets poorer
- Use Quality definition to break images into Good, Bad and Ugly categories
  - Identify features on images from each category and record percentage of area covered by each feature
  - Restore images
  - Identify features again and record areas identified
  - Observe how the areas change with restoration and between different qualities

Background





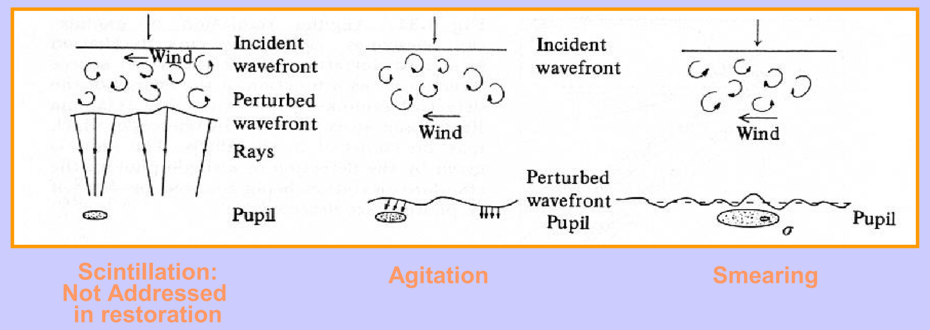


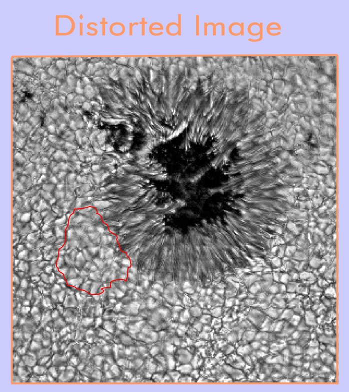


- Quality is average of width for each limb
- The sharper the image, the narrower the width

Image Restoration

- Turbulence in Earth's atmosphere bends wavefront
  - Scintillation
  - Agitation
  - Smearing





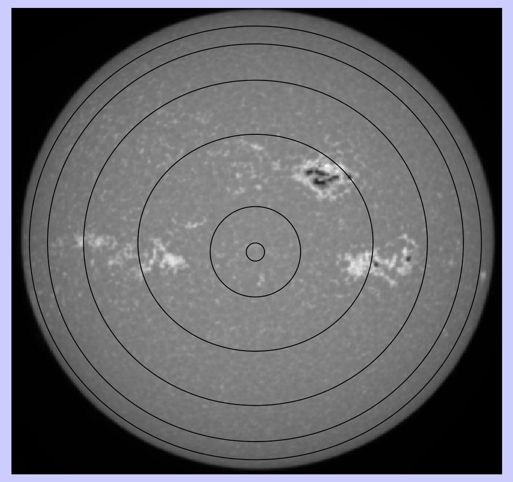
$$i(x,y)=i_0(x,y)*s(x,y)+n(x,y)$$

Observed Image; Unaltered Image; Point Spread Function(PSF); Noise

$$s(r)=C_1\{C_2 e^{-(r/b_1)^2}+C_3 e^{-(r/b_2)^2}+C_4 e^{-(r/b_3)^2}\}+\frac{a_1}{A(r^2+b_4^2)}$$

$$C_1=(1-a_1);\ C_2=(1-a_2)(1-a_3);\ C_3=a_2(1-a_3);\ C_4=a_3$$

Magnetic Structure Identification

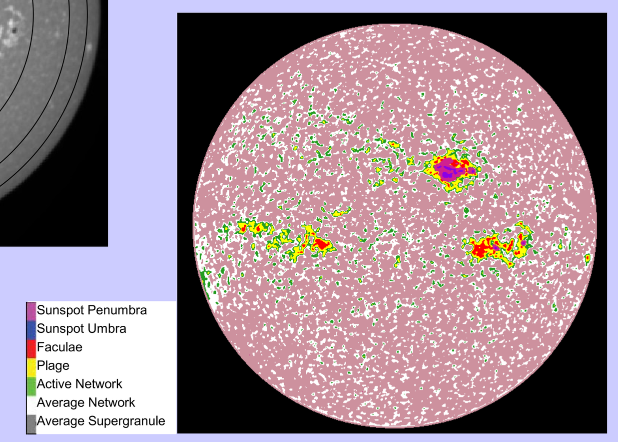


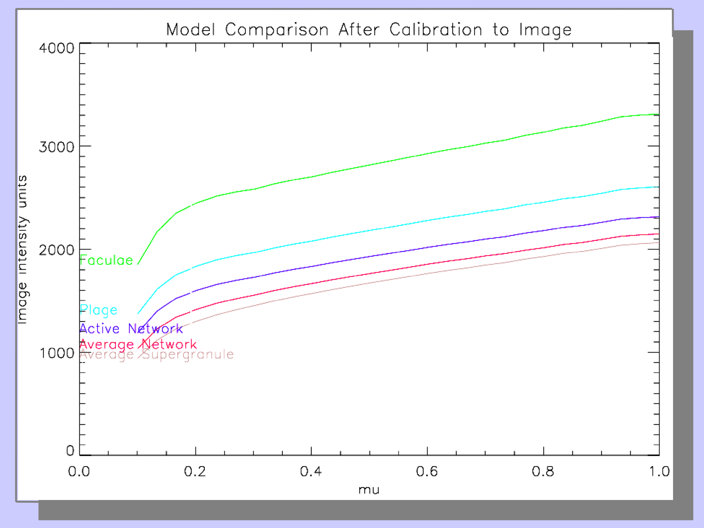
$$r_a=r_s\sqrt{1-\mu^2}$$

r_a = annulus radius

r_s = solar radius

μ = Cosine of Heliocentric angle





Results

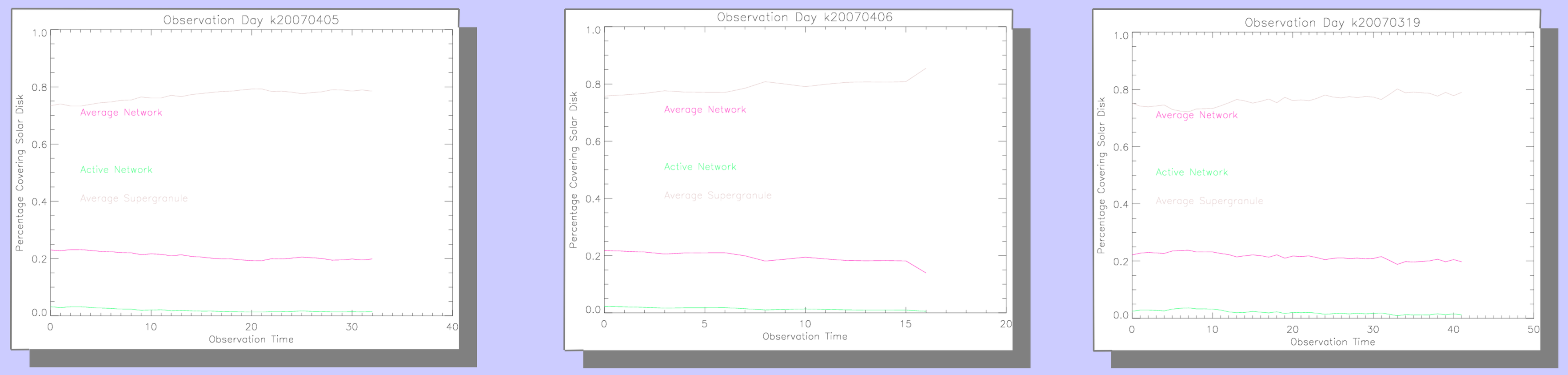
Table of percentages of areas identified for Pre Restoration and Post Restoration

Good Quality

date	Pre Restoration: Average Network	Pre Restoration: Active Network	Pre Restoration: Active Superganule	Post Restoration: Average Network	Post Restoration: Active Network	Post Restoration: Active Superganule	Change in Area: Average Network	Change in Area: Active Network	Change in Area: Active Superganule
20070318.1730	22.3	02.5	75.0	35.0	18.7	43.2	12.7	16.2	-31.8
20070318.1740	23.0	03.0	73.9	32.2	20.0	43.5	09.2	17.0	-30.4
20070405.1720	23.1	03.0	73.4	31.5	21.0	42.3	08.4	18.0	-31.1
20070405.1740	23.0	03.1	73.4	31.8	20.9	42.2	08.8	17.8	-31.2
20070405.1802	22.7	02.9	74.1	33.2	20.5	41.8	10.5	17.6	-32.3

Bad Quality

date	Pre Restoration: Average Network	Pre Restoration: Active Network	Pre Restoration: Active Superganule	Post Restoration: Average Network	Post Restoration: Active Network	Post Restoration: Active Superganule	Change in Area: Average Network	Change in Area: Active Network	Change in Area: Active Superganule
20070317.2102	21.1	01.7	77.0	38.7	16.0	42.5	17.6	14.3	-34.5
20070317.2120	20.4	01.5	78.0	41.6	15.1	42.0	21.2	13.6	-36.0
20070317.2220	20.2	01.5	78.2	36.2	17.8	43.3	16.0	16.3	-34.9
20070318.0020	18.7	01.1	80.2	45.2	12.4	41.7	26.5	11.3	-38.5
20070507.2240	20.6	01.6	77.7	41.3	17.0	39.9	20.7	15.4	-37.8



Summary and Conclusions

- Quality of an image decreases over an observation day
  - Sun is out longer and heats the atmosphere to cause more turbulence
- Active and average network increase with the Restoration of an image
- Active supergranule decreases with Restoration of image (Increased contrast leads to supergranule to be define as active or average network)
  - Change in area between restored and non-restored images is very large and most likely due to how restoration changes the profile of the sun.

Future Plans

- Perform restoration on all images over a single observation day. See how identified areas change. If restored correctly, all restored images would have same identified areas.
  - Compare the restoration of the worst quality image in a single day with the best unrestored image of that day
- Structure Identification
  - Structure models are normalized to annulus mean. Restoration changes the distribution of intensity, leaving the mean moderately unchanged. A better algorithm would normalise to something that varies with restoration.
- Image Restoration
  - Improve restoration algorithm to to not over restore an image
  - Restore no further than the best quality image of that observation day, or highest quality image taken by the PSPT
    - This will prevent restoration beyond the quality that the instrument will physically allow

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