Trends in the Short-Term SSI Variability over 100 Carrington Rotations from the UV through the Near IR

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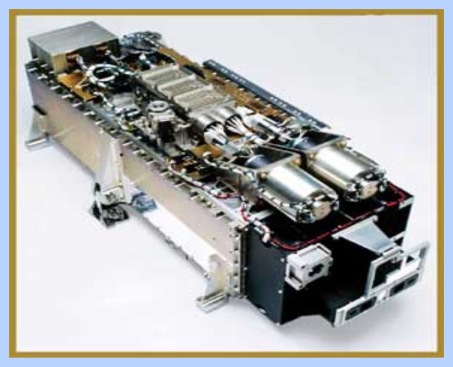
Summary

The Earth's atmosphere processes solar radiation in a wavelength dependent way, so it is impossible to fully understand the Sun's effects on Earth's atmosphere without a thorough understanding of all wavelengths in the spectrum. The Spectral Irradiance Monitor (SIM) onboard the SOlar Radiation and Climate Experiment (SORCE) is the first instrument of its kind to record the ultraviolet, visible, and infrared regions of the solar spectrum without atmospheric interference. The data from SORCE SIM was used to calculate a fractional energy difference based on an Mg II Index in order to better understand where the effects of solar features appear in the solar spectrum. These spectra were compared to synoptic maps of magnetic field from the Solar and Heliospheric Observatory (SOHO), measurements of total solar irradiance from the Total Irradiance Monitor (TIM) onboard SORCE, irradiance measurements between 200 and 320 nm from the SOLar STellar Irradiance Comparison Experiment (SOLSTICE), and a solar spectral irradiance prediction model.

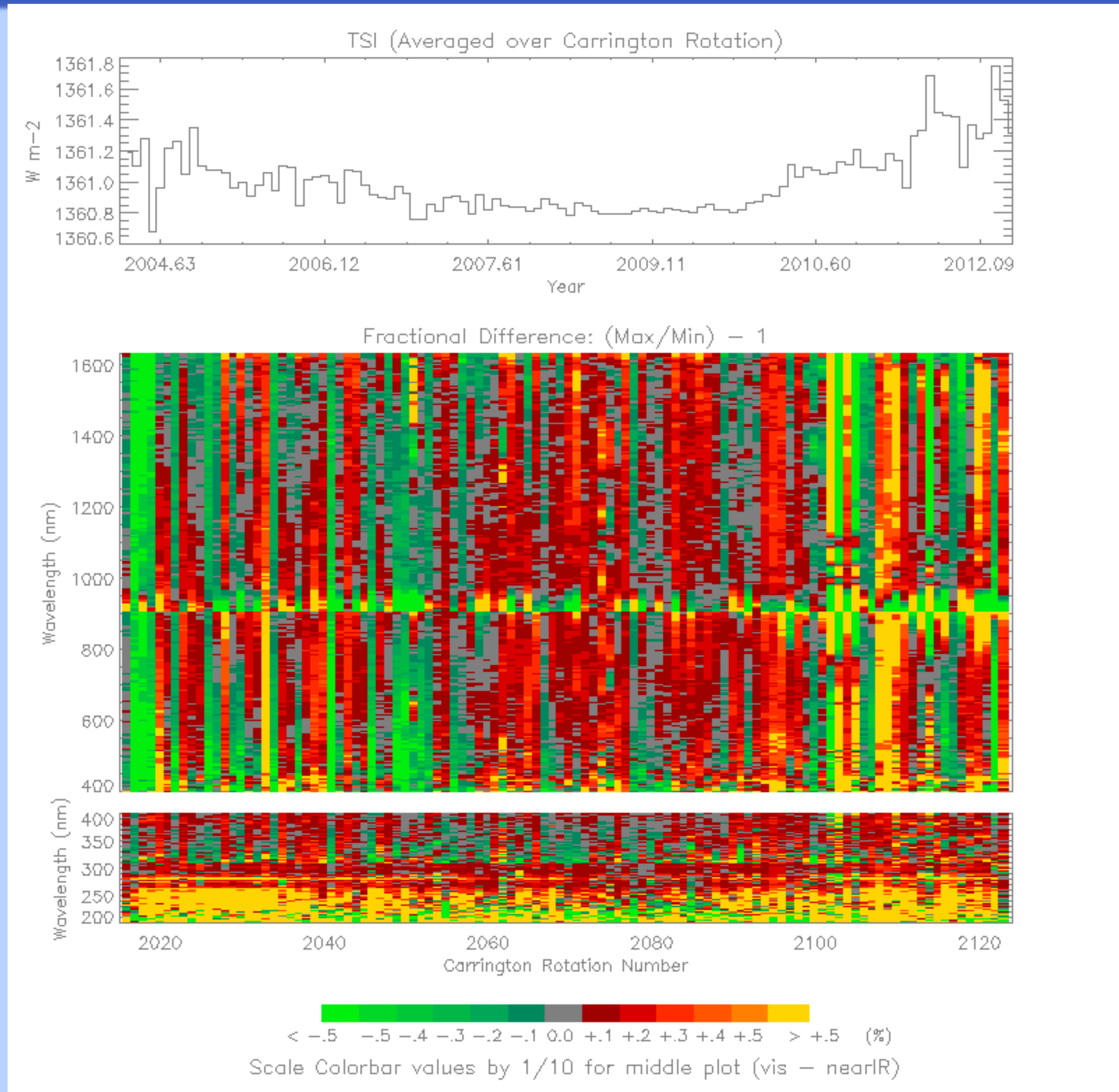
SIM Instrument

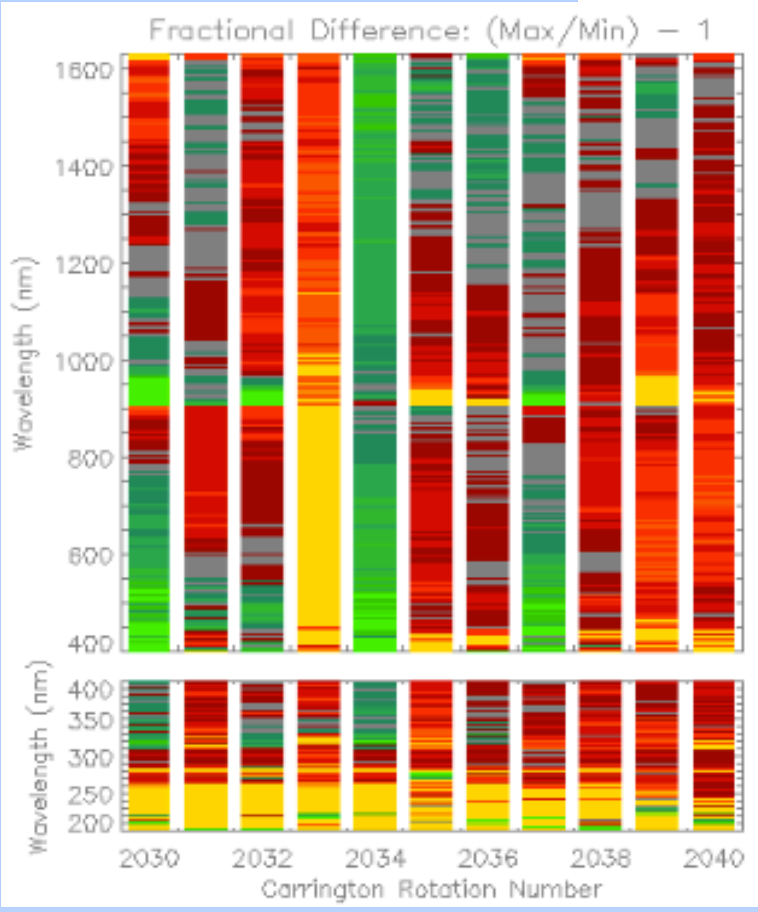


- Records from 200-2400 nm (UV to near IR)
- Uses a prism spectrometer with a combined standard uncertainty of about .1%
- The resolution of the instrument varies from 1 to 34 nm. The shortest wavelengths have the best resolution.
- Data have extremely high signal-to-noise

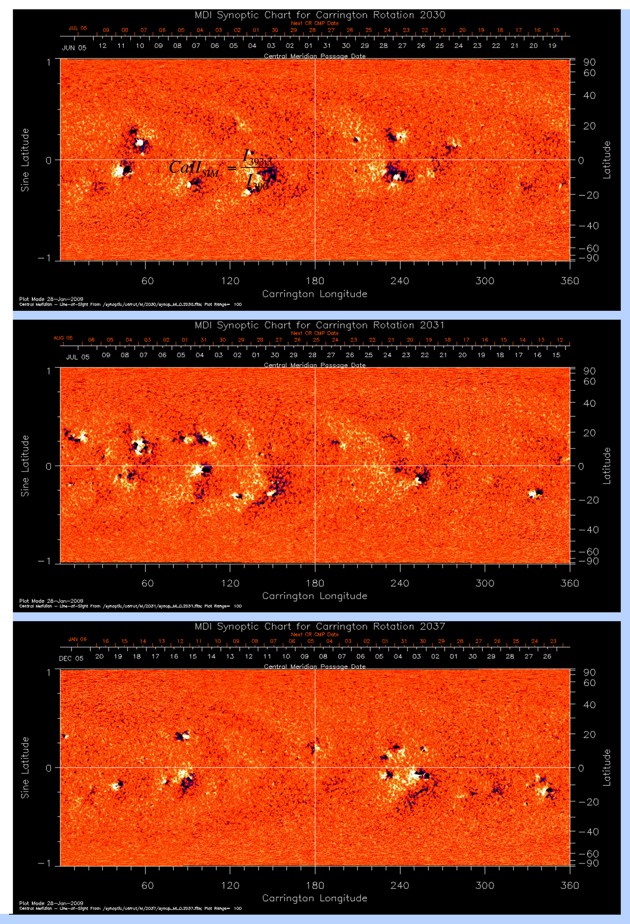
Data Analysis

After finding the maximum and minimum days based on the Mg II index in each Carrington Rotation, the fractional energy difference ($\frac{Max}{Min}-1$) of the SORCE SIM data was calculated for each wavelength. The plot of these results are in Figure 3, with bright colors (high variability) at the extreme positive or negative values and the dark colors and greys (little variability) near 0. The averaged TSI of each Carrington Rotation is plotted above the color plot.





Fractional difference plot CR 2030-2040



Synoptic maps of magnetic field

We focused on a time period of especially high variability (CR 2030 to 2040). The fractional difference plot and synoptic maps during this time period showed rotations with many sunspots were particularly noticeable in the spectrum. The sample time period was coming off of solar maximum so there was a large amount of activity.

Observations

- The most negative fractional differences in the sample size were in CR 2030, 2034, 2037. While these spectra were all primarily negative, CR 2030 had more variation. The red indicates dominance by plage brightening, and the green is dominancy by sunspot darkening. This manifests itself in the chromosphere and causes the general spectrum to not be as negative.
- Between CR 2037 and 2038, there was a change in time scale of Mg II maxima (i.e. 13 day repeat versus 27 day). The active regions switched hemispheres between Carrington Rotations 2037 and 2038.
- The Total Solar Irradiance map very closely follows the patterns in the visible part of the spectrum which sense because the Sun primarily emits in the visible.

Conclusions

- The fractional differences in solar spectral irradiance between 250 nm and 400 nm are predominantly positive, indicating dominance by chromospheric plage brightening in the UV into the visible parts of the spectra. Between 400 and 1600 nm, the fractional differences ranged from negative to positive indicating a balance between chromospheric plage brightening and photospheric sunspot darkening in the visible to the near IR part of the spectra.
- The Total Solar Irradiance best correlates with the patterns in the visible part of the spectrum because the Sun primarily emits in the visible.
- The Calcium II and Magnesium II indices are not as linear as the solar spectral irradiance model predicted.

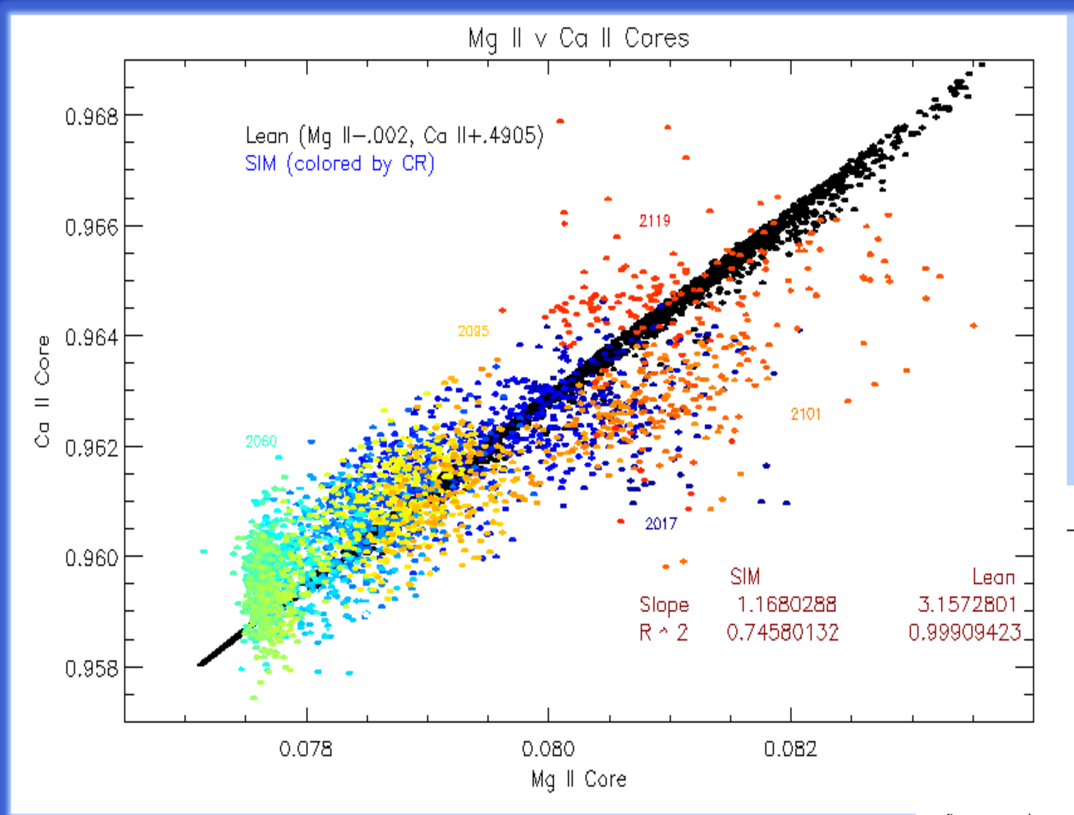
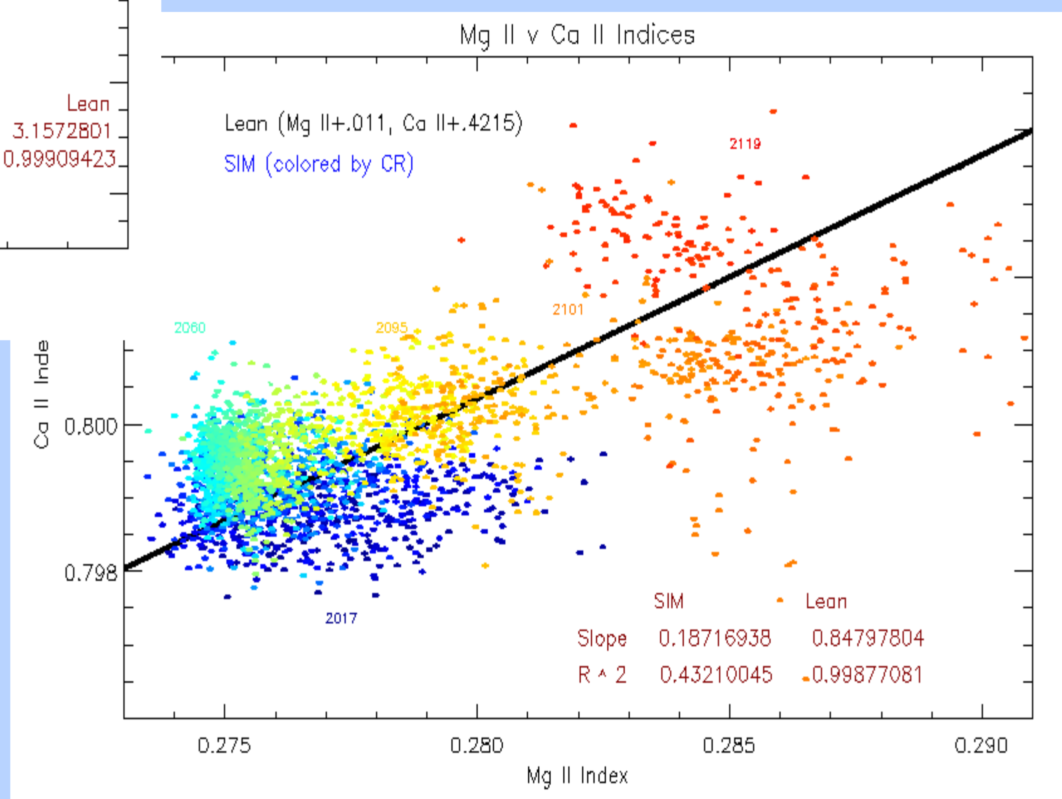


Figure 1 (above): This plot displays wavelength 280 (Mg II) versus wavelength 393 (Ca II). The black dots represent Judith Lean's model, which predicts a linear pattern between the two wavelengths. Our data appears in chronological order (navy blue to red), and follows Lean's model fairly closely, occasionally deviating above or below her curve. The variation toward the end of the time period is most likely instrumental, as SIM began power cycling in mid 2011.

Figure 2 (below): This plot displays the ratio of the irradiance of 393 nm (Ca II) to that of a second wavelength near 390 nm. The ratio of the two, while not an index, eliminates degradation and other instrumental effects. This causes the comparison to come out somewhat linear, as expected. However, while the Lean model shows less variability, the SIM data shows more variability as an index than in the raw data. This could possibly be due to the 5 nm precision of the SIM instrument at wavelength 393.



Calculations

After breaking up the data by Carrington Rotation, we found the maximum and minimum days in every single Carrington Rotation based on a Magnesium II index trusted to accurately reflect chromospheric activity.

$$MgII_{SIM} = \frac{4[I_{279.8} + I_{280.0} + I_{280.2}]}{3[I_{276.6} + I_{276.8} + I_{283.2} + I_{283.4}]}$$

We also considered using a Calcium II index, since both Mg II and Ca II reflect chromospheric activity (core) and photospheric activity (wings). However, the commonly used Ca II index requires a resolution around the Ca II feature of about .1 nm, while the SIM instrument has a resolution of about 3-4 nm at 393 nm. The Ca II had to be calculated in a similar manner, so we came up with a "pseudo index" for this feature.

$$CaII_{SIM} = \frac{I_{393.3}}{I_{390}}$$

Future Studies

- Study other parts of the solar cycle, particularly higher latitude sunspots at solar maximum
- Find other examples of hemispheric switch
- Further research the relationship between the Mg II and Ca II indices from real data.

References

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