1) Abstract

To understand Earth's climate, we must first understand the Sun. However, there are still significant uncertainties associated with both the fundamental mechanisms of solar variability and how they enter into the Earth's climate system. An important method to study the causes of solar variability can be found through the analysis of solar images. The Precision Solar Photometric Telescope (PSPT) located at the Mauna Loa Solar Observatory (Moloa) acquires images of the Sun in three different photometric bands to monitor the evolution of the solar surface features that change over the course of a solar cycle. These images provide a complete knowledge of the Sun by focusing on different layers of the solar atmosphere. Though raw images are meaningful and important, precision image processing is required to remove instrumental artifacts and false features that may appear in these images prior to usage for scientific purposes. Foremost among the artifacts that must be removed is the detector flat field that is determined by analysis of sixteen offset images that are analyzed through the Kuhn-Lin method. This algorithm is computationally intensive and the usage of a graphic processor unit (GPU) was studied to evaluate its effectiveness in improving code efficiency. A scientific application of the high precision solar images is investigated by analyzing a set of narrow bands of Calcium II K core and wing images. The core and wing images are processed to remove the influence of the center-to-limb variation; the resultant core-to-wing ratio image enhances the appearance of network structures on the entire solar disk along with the more obvious facula and plage brightening associated with the passage of active regions.

2) Solar Irradiance Problem

Earth's climate is entirely dependent on the Sun. Variations in the solar cycle alone constitute for 0.1% of the Earth's total energy. Therefore, there are compelling reasons to understand, analyze, and be able to predict changes in the Sun's features that affect the irradiance. However, it is not always so simple.

3) Precision Solar Photometric Telescope (PSPT)

The Precision Solar Photometric Telescope is located at the Mauna Loa Solar Observatory in Mauna Loa, Hawaii. PSPT has been acquiring daily images of the Sun since April 1998.

These images of the Sun give complete information of the Sun as seen in the figure below. The red filter image is biased towards photosphere and lower chromosphere and best shows the dark features of the Sun, including sunspots. The calcium II image is biased towards the upper chromosphere and highlights the brighter areas of the Sun including faculae, plage and active network.

4) Image Flat-Fielding

The process of removing instrument artifacts from these images is called flat-fielding. Though there are multiple methods for flat-fielding, the Kuhn-Lin method is used for these images. This involves taking sixteen offset images that span across the entire field of view in order to distinguish solar features from artifacts of the instrumentation as shown in the figure below.

The algorithm to generate the flat field is shown below. Due to the large data sets and extensive nature of the code, the execution time is around twenty to thirty minutes per flat field.

5) Core-to-Wing Imaging in Calcium II

An application PSPT image processing is to analyze solar images measured using narrow band filters centered on the core of the Ca II absorption filter that enhances chromospheric contributions and concurrent observations in its wing that has a greater photospheric contribution. In spite of the fact that the filter centers are only 0.25 nm apart in wavelength, their center-to-limb (CLV) are significantly different. A core-to-wing ratio is found by first ratioing each image by its CLV and then ratioing the core and wing images as discussed below.

6) Conclusion

Solar variability is an important but poorly understood component of the Earth climate system. The relationship between solar irradiance and the activity within the Sun is complicated and non trivial. However, different layers of the solar atmosphere radiate differently and this can be captured with image processing. Corrective image processing is essential for quality image analysis and advances in computer technology are required to match the advantages gained in image analysis. Core-to-wing image analysis in Calcium II for an entire solar cycle could provide meaningful information on the evolution of solar irradiance.

7) References