Modeling Solar Irradiance With the PSPT Solar Disk Observations and RISE Solar Spectrum Synthesis

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ABSTRACT

The PSPT (Precision Solar Photometric Telescope) at the Mauna Loa Solar Observatory provides full disk solar images from 200 nm to 2.0 µm (10 ppm at 1.35µm) and (2.0-5.1µm), allowing for the simultaneous observation of solar features in five broadband channels. The RISE (Radiation and Climate Experiment) satellite measures the full solar spectrum (200 nm - 2700 nm) with a goal of 300 ppm precision for irradiances. The RISE-RSPT comparison provides an opportunity to determine the accuracy of the analysis and calibration of the instrument. The PSPT images are efficiently analyzed using the PSPT/RISE Image Analysis Algorithm. The RISE/PSPT images are used to study the distribution and evolution of irradiance features on the solar surface. The goal of this study is to demonstrate the accuracy of the RISE-derived center-to-limb variation functions for each feature and position on the disk. We use the RISE-derived functions to compute a spectral irradiance for the solar disk. We compare the RISE-derived spectra for each feature and position on the disk. We present the results of a study of the physical origins of solar variability arising from variations of surface structures. We combine the above with spectral synthesis models of lines and broad spectral bands to compute a spectral irradiance for a particular state of the sun.

RISE Model Overview

- Studies the physical origins of solar variability arising from variations of surface structures
- Uses semi-empirical models of the solar atmosphere to synthesize the intensity spectrum from the observed irradiances
- Determines the distribution and evolution of surface features that contribute to irradiance variations
- Combines the above with spectral synthesis models of lines and broad spectral bands to compute a spectral irradiance for a particular state of the sun

PSPT/RISE Image Analysis Algorithm

1. Preprocessing (Both Images): The images are processed to remove effects of the CCD hot field, lens ghosts, and pixel noise, and harmonics of the instrument. Images are then normalized.
2. Mask Image: The images are normalized and divided by the instrument function to remove the effects of the flat field.
3. Masked Image: Each pixel assigned to a model
4. Output Image: Each pixel assigned to a model
   - Relative area of each model

Solar Irradiance Synthesis with the RISE Model

1. Compute Area-Weighted Average Disk Intensity
   \[ I_a(\lambda) = \sum \frac{I_{m,j}(\lambda)A_{m,j}}{\Delta\lambda} \]
   where:
   - \( I_{m,j} \) = Intensity of model \( m \) feature at weighted-center of the \( j \) annulus
   - \( A_{m,j} \) = Relative area of model \( m \) features in \( j \) annulus
   - \( I_a \) = Average Disk Intensity (Wm^-2nm^-1a^-1)

2. Compute Irradiance or Brightness Temperature
   \[ R = \sum \frac{I_{m,j}(\lambda)A_{m,j}}{\Delta\lambda} \]
   where:
   - \( R \) = Solid Angle of the Sun at 1 AU (6.7995 x 10^-5 sr)
   - \( I_a \) = Irradiance at 1 AU (Wm^-2 nm^-1)
   - \( T_b \) = Brightness Temperature (K)

Sample RISE-Synthesized Spectrum

Comparison of PSPT/RISE and SORCE Irradiances

- TIM and Visible-Band Irradiance Plot
  - TIM: 750nm “Visible” Irradiance from PSPT/RISE
  - Both data sets plotted: 200 ppm at 1.008 ppm from their means
  - Data show good general agreement, but much room for improvement