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Long-Term Trend Analysis for the Spectral Irradiance Monitor (SIM) and the Solar Radiation and Climate Experiment (SORCE)

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Abstract

The Solar Radiation and Climate Experiment (SORCE) mission of NASA is equipped with four instruments, one of which is the X-ray Photometer System (XPS). Key measurements of Total Solar Irradiance (TSI) and Solar Spectrum Irradiance were made by the SORCE spacecraft between 2003 and 2020 (SSI). The XPS is a collection of photometers used to gauge the sun's X-Ray Ultraviolet (XUV) irradiance at wavelengths less than 34 nm and the strong hydrogen emission at 121.6 nm. The accuracy of the XPS measurements is roughly 20%, and each photometer has a spectral bandpass of about 7 nm. Updates to the final data-processing algorithms are presented for the XPS solar-irradiance data products. Improvements to the instrumental adjustments for background signal, visible-light signal, and deterioration trends are included in these processing revisions.

The Solar Radiation and Climate Experiment/Spectral Irradiance Monitor (SORCE/SIM) instrument was launched on January 25, 2003, and its mission will end on February 25, 2020. The SORCE/SIM offers a singular data set of the variability in Solar Spectral Irradiance (SSI) throughout the descending portion of Solar Cycle 23 (SC23) from April 2003 to February 2009, the weaker solar-maximum circumstances of SC24, and the quiet SC24/SC25 low. The unmistakable identification of the impacts of the space environment and solar-exposure-related degradation mechanisms is necessary for the assessment of the size and phase of SSI fluctuations. The instrument-only SIM adjustments are based on a comparison of two functionally identical (mirror image) prism spectrometers with four independent detectors in each spectrometer channel.

Introduction

The Solar Irradiance Monitor (SIM) onboard the Solar Radiation and Climate Experiment (SORCE) spacecraft was designed, operated, calibrated, and performed as described in this article, which is the fourth in a series. The first outlines the instrument's scientific specifications, design, and operational modes. The pre-flight calibration procedure for the instrument is covered in the second, along with the basic measurement formulae. The third part of the article continues the discussion of the instrument's absolute calibration by outlining further post-launch characterizations using flight-spare parts and making comparisons with the SORCE, Upper Atmosphere Research Satellite/Solar Stellar Irradiance Comparison Experiment (UARS)/SOLSTICE, and Atmospheric Laboratory of Applications and Science (ATLAS) composite instruments. Discussions are held on additional in-flight comparisons with the European Space Agency's Scanning Imaging Absorption Spectrometer for Atmospheric Chartography instrument.

A major source of energy for terrestrial atmospheric processes is solar Ultra Violet (UV) light with wavelengths less than 320 nm. Through photoionization of molecules and atoms, photoexcitation, including resonance scattering, and photodissociation of molecules, solar UV photons are absorbed in the atmosphere of Earth. Solar energy with visible and Infrared (IR) wavelengths longer than 320 nm is partially absorbed by the atmosphere, scatters off clouds and particles, and can eventually reach the earth. The main source of energy for the global climate system is solar heating in the atmosphere and at the surface. For this reason, precise measurements of the Total Solar Irradiance (TSI) and Spectral

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Solar Irradiance (SSI) are essential for researching the radiative-energy balance, atmospheric photochemistry, and the role of the sun in regional and global climate change.

The TSI and SSI were monitored by NASA's Solar Radiation and Climate Experiment (SORCE) throughout its 17-year mission from 2003 to 2020. The results from the SORCE X-ray Photometer System in the X-Ray Ultraviolet (XUV) range of 0.1 nm to 34 nm and the intense hydrogen emission at 121.6 nm are what is being highlighted in this article. The SORCE's shortest-wavelength SSI instrument is the XPS. The neutral elements of the terrestrial atmosphere are photo-ionized by solar XUV radiation, and this process contributes to the ionosphere's development. Excitation, dissociation, and further ionization are caused by interactions between the photoelectrons produced in this process and the neutrals. Additionally, the extra energy produced by the absorption processes serves as the main source of energy for heating the thermosphere. The solar Lyman-emission at 121.6 nm is a major energy source for the photochemistry of NO, H_2O, and O_3 in the mesosphere and also contributes to ionization in the lower D-region of the ionosphere.

The sensitivity-loss processes can be identified independently and then physically meaningfully reintroduced into the measurement equation that calculates the response of the instrument by using terms that isolate them. The SIM Electrical Substitution Radiometer (ESR) and photodiode detectors' contributions to the measurement equation are covered in Sections respectively, and the prism transmission-degradation function is introduced in Section. This article explains how to calculate on-orbit adjustments to the pre-flight measurement equation. It's vital to remember that deterioration happens over time, both in terms of clock time and the amount of time the instrument is exposed to sunlight. These processes must be identified and independently accounted for in the equations used to assess overall deterioration, along with any accompanying uncertainties. The most important factors that contribute to deterioration are included and are broken down into effects that don't compound over time and effects that accumulate over time and cause irreversible trends in the irradiance time series. Because they provide the upper limit at which detectors and spectrometers may be compared, the short-term effects in this table are crucial for figuring out the long-term patterns in the time series. They effectively specify the precision of a single measurement.

The level of key component dependability and redundancy was defined following the five-year mission for which the SORCE spacecraft's power, attitude, and electronic systems were created. The SORCE spacecraft easily met all of its original lifespan specifications for a five-year mission; nevertheless, throughout the extended mission, adjustments to subsystem aging became an increasingly important component of preserving spacecraft and instrument health, especially after 2009. The mission-length time series of two of these data points demonstrates how easily the impacts of spacecraft safe-hold events and subsequent power cycling late in the mission can be detected. A ten-second cadence is used to check the detector and prism drive temperatures.

A quadrant-cell Fine Sun Sensor (FSS) is used to control solar pointing during solar observations and is reported in telemetry every ten seconds on the SORCE spacecraft. The SORCE spacecraft uses two independent methods to maintain solar pointing: (i) two redundant star trackers are used to maintain satellite orientation, especially during orbit night; and (ii) a quadrant-cell FSS is used to control solar pointing during orbit night. The FSS is firmly attached to the front of the SIM, and the bore sights of the two are aligned to within 0.5 arcmin. As a result, the readings from the FSS serve as an accurate gauge of the pointing off-axis of the SIM. Throughout the majority of the orbit, the spacecraft reaction-wheel system keeps SIM pointed at a distance of 0.5 arcmin. The only time this rule is not followed when a spaceship roll to avoid having the star trackers' performance be affected by Earth-derived light.