N95- 11125

PERFORMANCE EVALUATION OF THE SOLAR BACKSCATTER ULTRAVIOLET RADIOMETER, MODEL 2 (SBUV/2) INFLIGHT CALIBRATION SYSTEM

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Abstract

The Solar Backscatter Ultraviolet Radiometer, Model 2 (SBUV/2) instruments, as part of their regular operation, deploy ground aluminum reflective diffusers to deflect solar irradiance into the instrument's field-of-view. Previous SBUV instrument diffusers have shown a tendency to degrade in their reflective efficiencies. This degradation will add a trend to the ozone measurements if left uncorrected. An extensive in-flight calibration system was designed into the SBUV/2 instruments to effectively measure the degradation of the solar diffuser (Ball Aerospace Systems Division 1981). Soon after launch, the NOAA-9 SBUV/2 calibration system was unable to track the diffuser's reflectivity changes due, in part, to design flaws (Frederick et al. 1986). Subsequently, the NOAA-11 SBUV/2 calibration system was redesigned and an analysis of the first 2 years of data (Weiss et al. 1991) indicated the NOAA-11 SBUV/2 onboard calibration system's performance to be exceeding preflight expectations. This paper will describe the analysis of the first three years NOAA-11 SBUV/2 calibration system data.

1. Introduction

The Solar Backscatter Ultraviolet Radiometer, Model 2 (SBUV/2) launched on the NOAA-11 weather satellite in September 1988 is the latest in the SBUV family of satellite-borne radiometers using the solar backscatter technique for monitoring atmospheric ozone. The SBUV/2 instrument, based on the NIMBUS-7 SBUV design (Heath et al. 1975), is a scanning double monochromator which measures either the backscattered atmospheric radiance or the incident solar irradiance over the wavelength range 160 to 405 nm. The monochromator radiative input can be from either the nadir direction for direct atmospheric viewing or via a reflective diffuser plate of ground aluminum for solar irradiance measurements. The SBUV/2 can measure at twelve preselected discrete wavelengths over a 32 second period sequence or sweep through the entire spectral range in steps separated by approximately 0.15 nm. The integration time for each step is 0.1 second with an entire sweep taking 192 seconds to complete.

The onboard calibration system, used to measure changes in the solar diffuser's relative reflectivity consists of a mercury (Hg) lamp whose output can be directed into the SBUV/2's field-of-view directly or via the solar diffuser. The entire reflectivity measurement sequence consists of ten sweeps of the Hg lamp, mixing direct and diffuser views in succession. The relative diffuser reflectivity at a given Hg emission line is calculated by taking the ratio of the integrated intensity observed off the solar diffuser (diffuser view) to the integrated intensity observed directly from the lamp (direct view). An average reflectivity is calculated from three successive diffuser/direct scan pairs at ten mercury emission lines (185.0, 253.7, 265.3, 289.4, 296.8, 302.1, 312.6, 334.2, 365.1, and 404.7 nm).

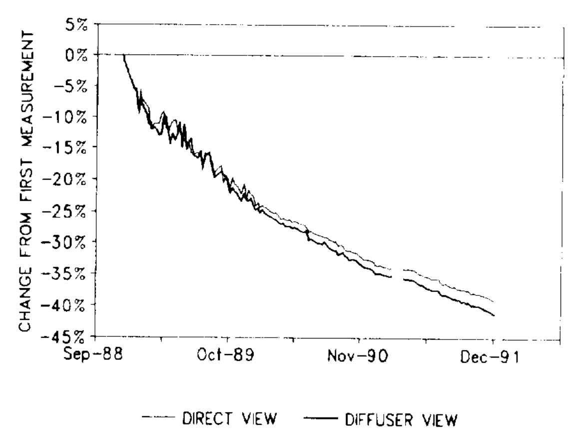

Figure 1: NOAA-11 SBUV/2 Daily Average Mercury Lamp Intensity at 253.7 nm

NOAA-9 SBUV/2 experienced lamp output deviations of 3% to 4% during a single calibration sequence (Frederick et al. 1986). This apparent lamp output instability was caused, in part, by a sensitivity of the instrument to the non-uniform illumination of the instrument field-of-view (IFOV) by the calibration lamp. Consequently, the NOAA-11 SBUV/2 mercury lamp assembly was modified to insure a uniform illumination of the IFOV (Weiss et al. 1991).

2. NOAA-11 SBUV/2 Diffuser Relative Reflectivity

One of the concerns about the performance of the calibration system is whether the mercury lamp would be an effective radiant source over the life of the mission. This means maintaining an acceptable signal to noise level at the calibration wavelengths. Time series plots of the NOAA-11 SBUV/2 show the lamp output decreases as much as 40% at 253.7 nm (Figure 1) to 25% at 404.7

nm (Figure 2) over the first three years of operation. An increase in the signal to noise occurred at four weaker mercury lines (265.3, 289.4, 302.1, and 334.2 nm) because of the diminution of the lamp output. This increase in noise affected the usefulness of the relative reflectivity calculations at these wavelengths. At the present lamp output degradation rate of about 40% in three years, these four lines will not produce useful reflectivity measurements after two more years of operation. However, the signal level of reflectivity measurements at the six stronger mercury lines do not seem to be affected adversely.

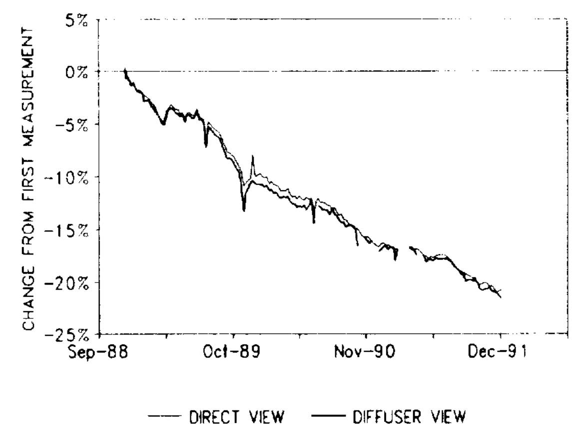

Figure 2: NOAA-11 SBUV/2 Daily Average Mercury Lamp Intensity at 404.7 nm

Daily averages of the measured relative reflectivity were calculated for the NOAA-11 SBUV/2 diffuser from December 1988 to December 1991. Measurements were taken approximately every seven days except during the first three months, when the calibration sequence was initiated every four days. Figures 3 and 4 display representative time series plots of daily average relative reflectivity measurements for two lines (253.7 nm and 404.7 nm, resp.). The linear decrease with time in the relative reflectivity is seen at all wavelengths. The apparent difference in the magnitude of the decrease with wavelength varies from about 0.5% per year at 400 nm to 1.5% per year at 185 nm (Figure 5).

An increase in the variability of the daily average reflectivity occurred for each mercury wavelengths shortward of 404.7 nm over a one year period (from January 1989 to January 1990). An erratic electro-mechanical malfunction in the grating positioning system caused small discrepancies in the sweep-to-sweep line intensities over a 10-sweep sequence. This problem has appeared only in the spectral sweep mode, from which the relative reflectivities are calculated. It has not appear in the discrete mode in which the operational ozone measurements are made. After February 1990, the malfunction progressed to the point of producing a constant sweep-to-sweep wavelength offset effectively stabilizing the mercury lamp measurements. The SBUV/2 instrument contractor, the Ball Aerospace Systems Group, has developed an adjustment to the grating system electronics which should reduce or eliminate this problem on subsequent SBUV/2 calibration systems' operations.

Diffuser degradation rates were calculated from linear regression analysis of the ten mercury lines reflectivity times series

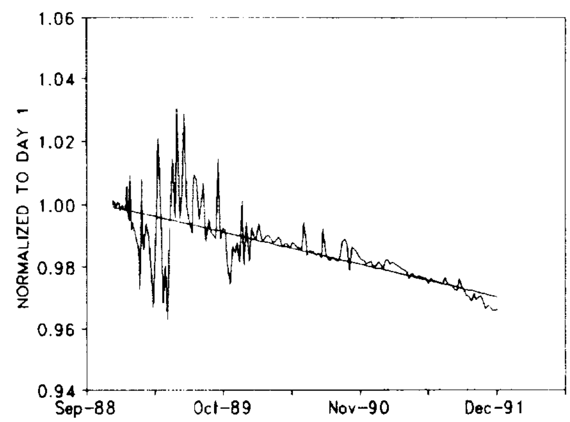

Figure 3: NOAA-11 SBUV/2 Daily Average Relative Reflectivity at 253.7 nm; Line is Linear Fit; Large Deviations During the First Year Due to Grating System Problem

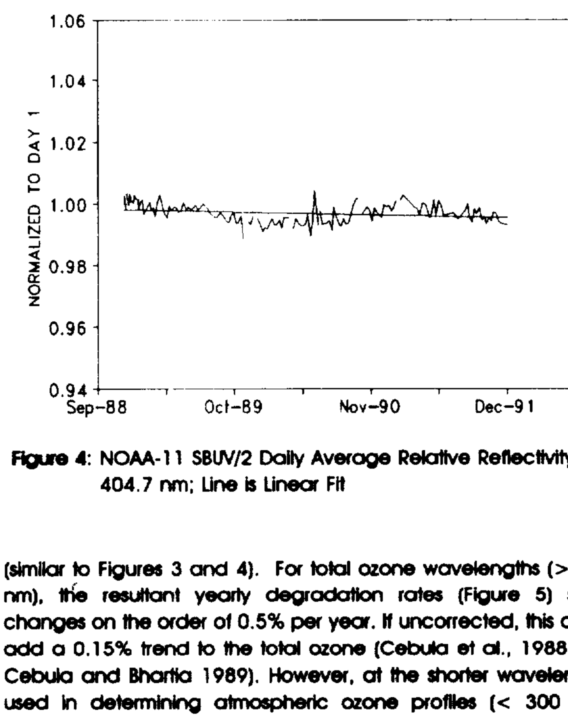

Figure 4: NOAA-11 SBUV/2 Daily Average Relative Reflectivity at 404.7 nm; Line is Linear Fit

(similar to Figures 3 and 4). For total ozone wavelengths (> 300 nm), the resultant yearly degradation rates (Figure 5) show changes on the order of 0.5% per year. If uncorrected, this could add a 0.15% trend to the total ozone (Cebula et al., 1988 and Cebula and Bhartia 1989). However, at the shorter wavelengths used in determining atmospheric ozone profiles (< 300 nm), degradation rates increase from 0.5% to as much as 1.5% per year. Such a change would add an approximate 3% per year trend in 1 millibar ozone if left uncorrected.

Gu et al. (1992) applied the new self-calibration method developed for the NIMBUS-7 TOMS/SBUV instruments (Herman et al. 1991) to the NOAA-11 SBUV/2 and calculated degradation rates consistent with these calibration system results. They concluded the calibration error for the derived total ozone over the first 2.5 years for NOAA-11 SBUV/2 operation was no more than 1 Dobson unit.

3. Summary

The performance of the NOAA-11 SBUV/2 onboard calibration system over the first three years of operation has been within preflight expectations. The measured diffuser degradation rate is similar to that deduced for the NOAA-9 SBUV/2 (Frederick et al. 1986). The rate is small for the wavelengths used for the total ozone measurements, adding only 1 Dobson unit error over 2.5 years. The effective rates at the shorter wavelengths are larger and will be taken into account in the next reprocessing of the ozone products (W. Planet, privet communication). The SBUV/2 lamp-based calibration systems are one of a few onboard calibration systems used for monitoring diffuser properties. Jaross et al (1992) has reported of the successful operation of a multiple diffuser system used to monitor diffuser properties on the Meteor-3/TOMS satellite.

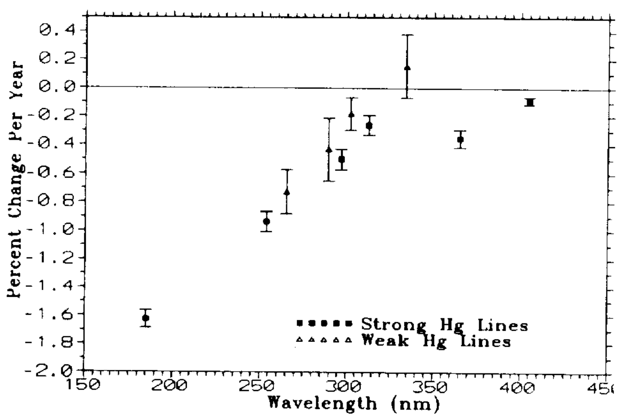

Figure 5: NOAA-11 SBUV/2 Diffuser Reflectivity Degradation Rates Derived from 3 Year Regression Analysis of Daily Averages

4. ACKNOWLEDGMENTS

The authors would like to thank W. Nelson, A. Fegley, and K. Kelly of the Systems Group at Ball Aerospace in Boulder, Colorado and W. Planet, J. Leinesch, and D. Bowman at the Physics branch of NOAA/NESDIS in Suitland, Maryland. This research was done under contract to the Laboratory for Atmospheres at the NASA/Goddard Space Flight Center under NASA contracts number NAS5-34286 and NAS5-31380.

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