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SSBUV MIDDLE ULTRAVIOLET SOLAR SPECTRAL IRRADIANCE MEASUREMENTS

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ABSTRACT

The SSBUV instrument performs multiple solar spectral irradiance measurements in the wavelength region 200 to 400 nm at 1.1 nm resolution during yearly Space Shuttle flights. Solar spectral irradiance observations from the first three SSBUV Shuttle flights, October 1989, October 1990, and August 1991, are compared with one another and with solar measurements made by the NOAA-11 SBUV/2 instrument. The repeated SSBUV solar spectral observations, which agree to within ±1-2% from 200 to 400 nm, are valuable not only as a means of validating and calibrating the satellite-based solar irradiance measurements, but also as a distinct set of stand-alone solar measurements for monitoring long-term changes in the solar spectral irradiance, which are important for ozone photochemistry.

1. INTRODUCTION

Solar ultraviolet (UV) radiation in wavelength region 200 to 350 nm is the major driving force behind the production and destruction of stratospheric ozone (Hood and Jirikowic, 1991). Short and long-term ozone changes caused by solar variations must be fully understood in order to identify anthropogenic trends in total column ozone amount and ozone vertical profile. Unfortunately, uncertainties in the middle UV solar spectral irradiance measurements are of the same magnitude as both 27-day solar rotation and 11-year solar cycle irradiance variations (Lean, 1991; Cebula and DeLand, 1992), complicating the assessment of the solar change contribution to the observed long-term ozone trends.

The Shuttle Solar Backscatter Ultraviolet (SSBUV) experiment is providing repeated UV solar irradiance measurements on a near decade-long time scale with an instrument that is calibrated preflight, in-flight, and post-flight. SSBUV is designed to provide a direct calibration of the long-term ozone and solar spectral irradiance measurements made by the NOAA SBUV/2-series operational ozone monitoring instruments (Hilsenrath et al., 1988, 1992a, 1992b). SSBUV calibration methods and results are discussed in Cebula et al. (1989, 1991b) and Hilsenrath et al. (1991). During Shuttle flights spaced at approximate one year intervals, the SSBUV instrument performs multiple solar spectral irradiance measurements in the wavelength region 200 to 400 nm at 1.1 nm resolution. Solar spectral irradiance observations from the first two SSBUV Shuttle flights, October 1989 and October 1990, including preliminary comparisons with solar measurements made by other middle UV solar irradiance monitors have been reported previously (Cebula et al., 1991a; Cebula and Hilsenrath, 1992). Since our last report, the SSBUV experiment has flown twice more on the Shuttle, in August 1991, and most recently along with the ATLAS pallet in March 1992. We here report on preliminary analysis of the August 1991 solar data; data from the most recent mission will be reported at a later date.

2. DISCUSSION

SSBUV observed the sun three times during its first mission. Four solar observations were taken during both the second and third missions. The solar data from each mission were processed using that mission's corresponding postflight calibration because the postflight calibration is more representative of the instrument's sensitivity during the mission than is the preflight calibration. The SSBUV-1 solar irradiance data have been reprocessed using an revised calibration, but differ from those presently previously (Cebula and Hilsenrath, 1992) by less than 1%. Figure 1 presents the solar irradiance measured by SSBUV during the third mission, with several strong solar features, the Al absorption edge near 210 nm, the unresolved Mg

II h and k doublet at 280 nm, the Mg I singlet at 285 nm, and the Ca II H and K lines at 396.8 and 393.4 nm, respectively, identified.

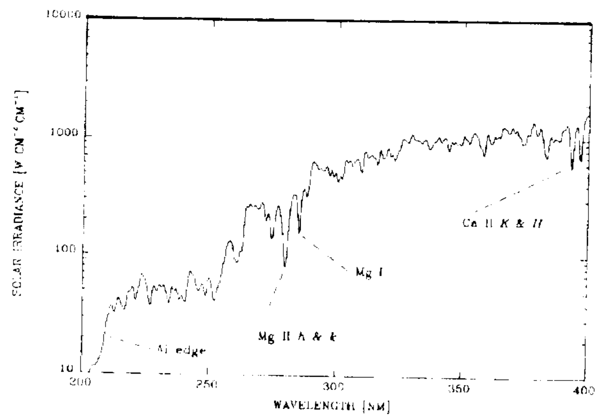

Fig. 1. Average solar spectral irradiance measured by SSBUV, 3-6 August 1991.

The ratio of the average solar irradiances observed during the SSBUV-2 and SSBUV-3 missions to the average solar irradiance observed during the SSBUV-1 mission are presented in Figure 2. The observed mission-to-mission differences could arise from wavelength dependent changes in the solar output, uncompensated wavelength dependent instrument sensitivity change, or a combination of both sources. Solar variations can be estimated using the Mg II proxy index and scaling factors (DeLand and Cebula, 1992). We have derived a Mg II index for each SSBUV solar measurement. The SSBUV Mg II indexes from the first two missions differ by less than 0.5%, indicating little difference in solar UV output for these missions. The mean SSBUV-3 Mg II index was nearly 3% larger than the mean index from the first two missions, indicating a larger solar UV output during this flight. Concurrent NOAA-11 SBUV/2 solar observations establish that this increase is due to the coincidence of the SSBUV-3 mission with the peak of a 27-day solar rotation cycle rather than a long-term change in solar UV output. Ratios of the SSBUV-3 and the SSBUV-2 spectral irradiances to the SSBUV-1 spectral irradiance, Figure 2, exhibit a repetitive structure in the 250 to 350 nm region, which, coupled with the expected minimal solar irradiance changes longward of 250 nm, suggests a residual ±1% relative error in the SSBUV-1 irradiances with respect to the later missions. The SSBUV-1 instrument sensitivity changes were nearly a factor of two larger than the sensitivity changes observed on the SSBUV-2 mission and almost a factor of five larger than the sensitivity changes observed during the SSBUV-3 mission. Hence, we feel that the SSBUV-1 irradiances are slightly more uncertain than the irradiance values from the latter missions. Nevertheless, the agreement between each mission, including SSBUV-1, is very good and represents the state-of-the art in middle UV multiple-mission calibration.

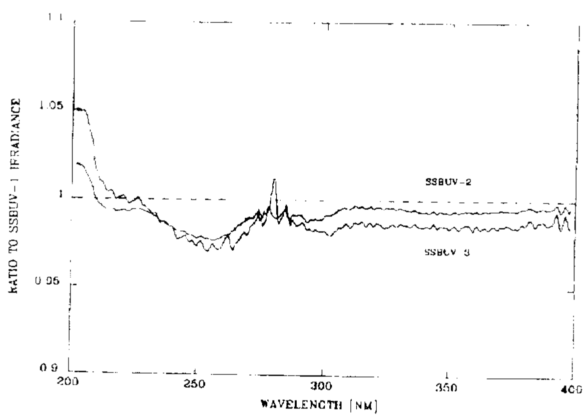

Fig. 2. Ratio of the SSBUV-2 and the SSBUV-3 solar spectral irradiances to the SSBUV-1 values.

The sharp increase in the SSBUV-3/SSBUV-1 irradiance ratio at the Al edge shown in Figure 2 is consistent with the solar irradiance change predicted by the Mg II index. Figures 3 and 4 investigate this further. Figure 3 presents the solar change measured from the SSBUV-2 to SSBUV-3 missions (assuming the observed change in measured irradiance is entirely due to solar change), together with the solar change predicted based on the SSBUV Mg II index. Figure 4 shows the percent difference between the Mg II index-predicted and the measured solar spectral

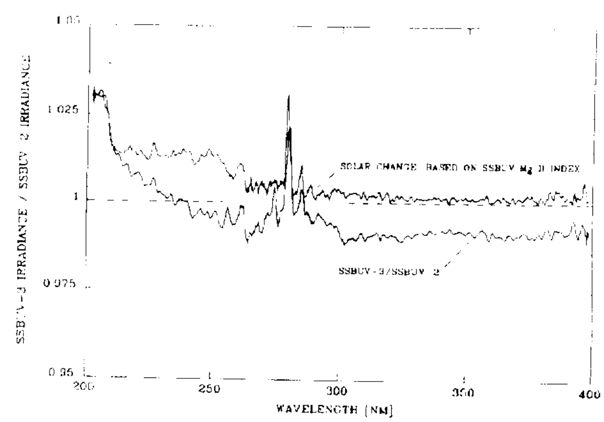

Fig. 3. Solar change as measured by SSBUV: August 1991/ October 1990, compared to solar change predicted by the SSBUV-measured Mg II index and scaling factors.

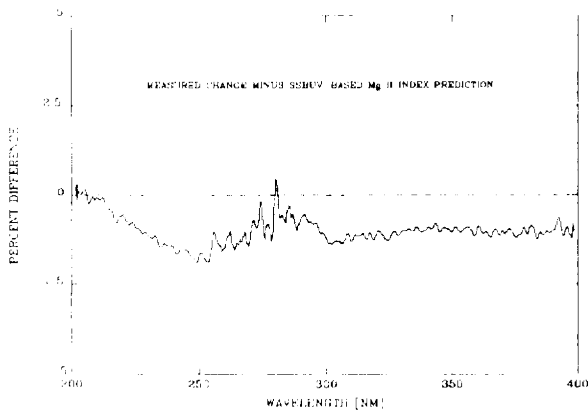

Fig. 4. Difference in the SSBUV-measured and Mg II index-predicted solar spectral irradiance change: August 1991/October 1990.

irradiance change. The 1% offset is within our calibration uncertainty estimates and most probably reflects a small relative calibration error. The less than ±1% spectral difference could arise from spectral calibration errors and/or error in using the Mg II index and scaling factors to estimate long-term solar change. In any case, this is a very small difference.

Figure 5 presents the ratio of the NOAA-11 SBUV/2 and SSBUV solar spectral irradiances for each of the three SSBUV missions, relative to the

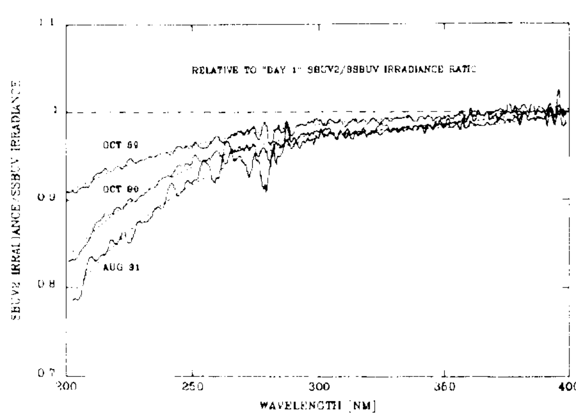

Fig. 5. Ratios of the NOAA-11 SBUV/2 and the SSBUV measured solar spectral irradiances, October 1989, October 1990, and August 1991, relative to the "Day 1" ratio. These curves indicate uncorrected drift in the satellite instrument. The dashed lines represent third order polynomial fits to the data.

SBUV/2 to SSBUV irradiance ratio constructed from the first (or "Day 1") observations from each instrument. This presentation removes differences in the measured irradiances due to absolute radiometric calibration errors. The satellite measurements were not corrected for instrument radiometric sensitivity drift. Hence, these comparisons indicate a substantial wavelength dependent drift in the satellite instrument's sensitivity, ranging from less than 1% at 400 nm to as much as 22% at 200 nm over the period December 1988 through August 1991. These comparisons show that the SSBUV solar data can be used to monitor and correct for changes in the spectral radiometric sensitivity of the SBUV/2-series instruments.

3. CONCLUSIONS

Intercomparisons of the solar spectral irradiance data from the first three SSBUV Space Shuttle missions shows that the SSBUV experiment is providing solar spectral irradiance measurements which are accurate with respect to one another to within ±1-2% over the 200 to 400 nm region. While each SSBUV mission provides only a snapshot of the middle ultraviolet solar output, the SSBUV data can be used in conjunction with the corresponding SBUV/2 satellite instrument data to monitor both short-term and long-term solar spectral irradiance variations in this photochemically important region.

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