N95- 10647

Characterization and Analysis of the Nimbus-7 SBUV data in the "Non-Sync" Period (February 1987 - June 1990.)

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Introduction

The SBUV instrument, on Nimbus-7, measures the backscattered ultra-violet radiance at 12 wavelengths. The radiance data from these wavelengths was used to deduce the ozone profile and the total column ozone. In February 1987, there was an instrument malfunction. The purpose of this paper is to describe the malfunction, to determine the effect of the malfunction on the data quality and if possible, to correct for the effects of the malfunction on the data from the SBUV instrument.

Instrument Description

The SBUV instrument consists of both a monochromator for dispersing the light into the ozone wavelengths and a single wavelength photometer for monitoring the reflectivity of the Earth. The two parts share a common chopper wheel and counting electronics. The SBUV photometer measures the radiance at 343 nm, using a filter/photodiode combination. The photometer data are coincident with the data from each monochromator channel. The absolute reflectivity is derived from the 339.8nm monochromator channel and the photometer data to monitor the changes in the earth reflectivity as the instrument collects data at each wavelength channel. Additional instrumental details can be found in Appendix 1.

The SBUV chopper wheel chops the optical signal just prior to the entrance slit. This chopping enables the instrument to compensate for the background signal induced by the energetic particle radiation in the space environment. The background signal gets significantly higher as the spacecraft passes through high radiation environments, e.g., the South Atlantic Anomaly. The lack of a chopped signal affected the data quality from the earlier Nimbus-4 BUV instrument.

The chopper wheel was synchronized to the counting electronics. The counter would count up with the slit open and count down with the slit closed. Beginning February 13, 1987, the chopper wheel and the counting electronics started to become non-synchronized. By mid-summer 1987, the non-synchronization was complete and all the scans were taken with the chopper and the counter out of synchronization.

Assessing the Instrument in the Non-Sync Period

The SBUV instrument makes weekly solar flux measurements using the 12 ozone wavelengths. The photometer data are also collected during this set of measurements. The photometer solar flux at 343 nm should be constant during the measurement cycle (10 scans of 32 seconds each). The distribution or the variation of the solar flux data from the photometer should give us an idea of how "out of sync" the chopper wheel and the counting electronics really are. A time series of the discrete mode solar photometer measurements is shown in fig 1. The start of the non-sync period is easily observed in fig 1, in early 1987.
Diffuser plate calibration errors will cause a small variation in the photometer measurements. Note that after the start of non-sync, the distribution of the solar photometer data increases. The standard deviation of the monthly average solar photometer will give us a qualitative measure of the nonsync condition. The standard deviation

time series plot, fig 2, shows very stable standard

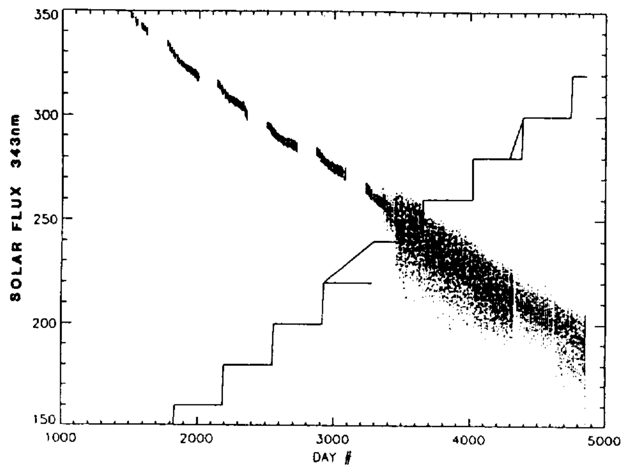

Figure 1: Solar photometer data at 343 nm for each wavelength for each scan for the months January to June, for the years 1983 to 1991.

deviation prior to February 1987, an increase in the standard deviation in 1987 as the out of sync rate approached 100%, then a plateau through the spring of 1990.

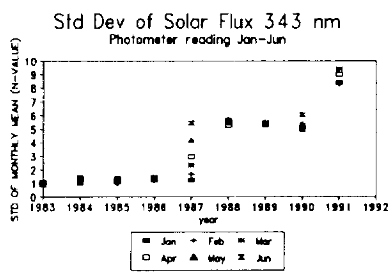

Figure 2:The standard deviation of the monthly mean solar photometer flux for the months January to June, for the years 1983 to 1991.

The consistency of the photometer solar flux standard deviations indicates that the instrument was fairly stable and that the amount of non-synchronization was not changing. In the summer of 1990, the TOMS instrument, which is attached to and shares common electronics with the SBUV, began to have non-sync problems. The occurrence of the TOMS non-sync was thought to be temperature related and SBUV was put in a different mode to add heat to the spacecraft, in an attempt to correct the TOMS problems. After normal SBUV operations were resumed, the SBUV instrument was in a different state, as shown by the increase in the standard deviation of the solar photometer data.

The solar data indicate that the instrument had gone out of sync in Feb 1987 and reached a stable state where it remained until the summer of 1990. Since the out of sync condition appeared to be stable we believe that the earth radiance data can be corrected for the nonsync condition and more accurate ozone values can be retrieved from the SBUV instrument.

Correction of the Non-Sync Data

As the photometer and the monochromator view the same area, at the same time, at two different wavelengths, we can use these simultaneous measurements to compensate for the non-synchronous chopper wheel.

The photometer responds to changes in the earths reflectivity at 343 nm. The reflectivity that the photometer measures should not change very much over a single SBUV scan, 1.5 sec between each of 12 wavelengths. Five consecutive photometer scans before the non-sync period are shown in fig 3, note the smooth, monotonic photometer signal within a single scan. A larger deviation will occur between consecutive scans due to the 12 second gap between them.

Five consecutive scans from the non-sync period are shown in fig 4, note random scatter within a single scan. The scatter observed in the photometer data is caused by the nonsynchronous chopper wheel and not by changes in the earth's albedo.

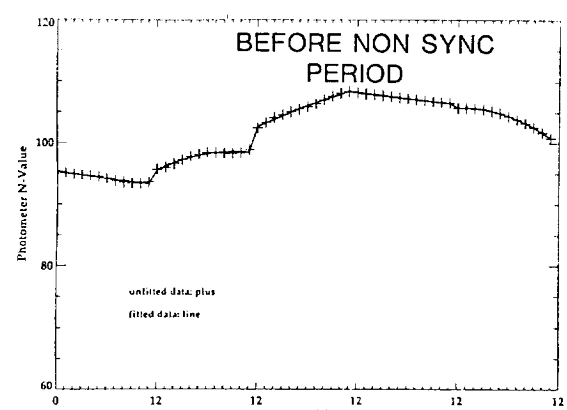

Figure 3: The equatorial photometer values from 5 scans before the start of the chopper wheel non-sync problem. The line is a quadratic fit through the 12 points of each of the scans.

Since the photometer and the monochromator view the same scene at the same time, the deviation in a single photometer reading will be proportional to the deviation in the simultaneously measured monochromator ozone wavelength. By smoothing the photometer data within a single scan, we can remove the variation caused by the nonsynchronous chopper wheel.

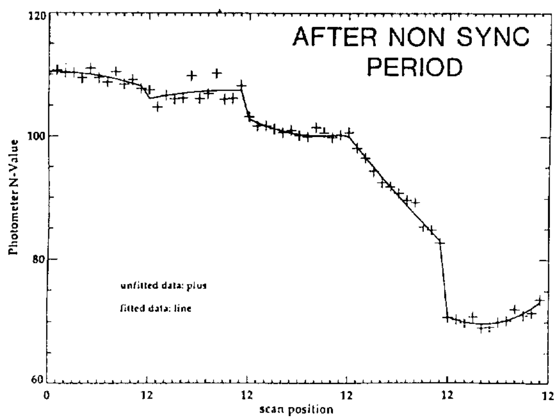

Figure 4: The equatorial photometer values from 5 scans after the start of the chopper wheel non-sync problem. The line is a quadratic fit through the 12 points of each of the scans.

The ratio of the smoothed to unsmoothed photometer data, from a single scan, can be used to correct the monochromator data from that scan.

Our correction technique consists of fitting a quadratic expression to each photometer scan. Any outlier, a point which is greater than 2 standard deviation from the fitted point, is replaced with the fitted value and the scan is quadratically fit again. The ratio between the fitted and the unfitted photometer data is used to correct the monochromator data for that scan.

$$\text{Ratio} = 1 - (\text{Photometer}_{fit} - \text{Photometerun}_{fit})/\text{photometer}_{unfit}$$

For each scan, the photometer ratio is calculated at every wavelength, ratio at each wavelength is multiplied by the monochromator albedo from that wavelength. The corrected monochromator albedos are used in the inversion algorithm to calculate ozone profile and total column ozone.

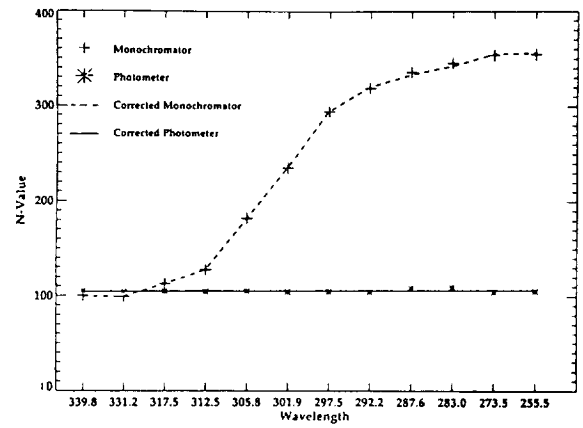

Figure 5: An example of a single scan showing the corrected and uncorrected photometer data with the corresponding monochromator data.

Ozone Results using the Corrected Data

The corrected data had a dramatic effect on individual ozone profiles. The magnitude of the albedo corrections can be relatively small, and still have a significant impact on the retrieved ozone profile. In fig 5, the original and the corrected data are shown, and the corresponding ozone profiles are shown in fig 6.

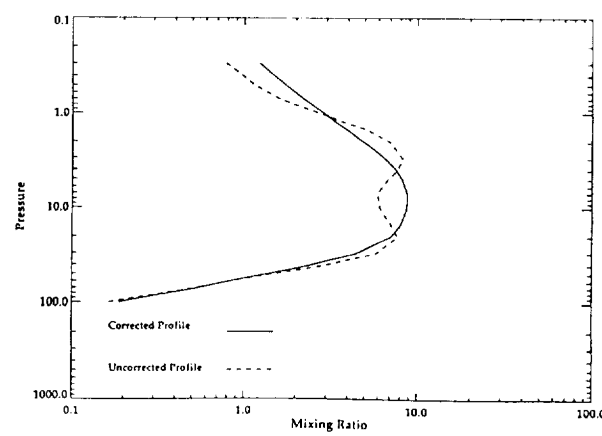

Figure 6: A single ozone profile retrieved from using the data in figure 5.

The zonal mean profile data also showed a significant improvement. The standard deviation of the monthly zonal means improved significantly. The results for May, 15S -15N, for Umkehr layers 4 to 9 are shown in figs 7 and 8.

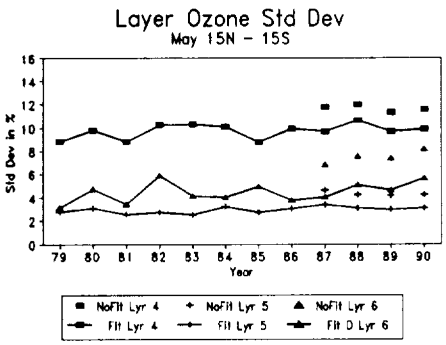

Figure 7:This shows the standard deviation in % of monthly zonal mean, for the month of May for layers 4,5, and 6. The standard deviation calculated using the uncorrected data is shown by symbols without the line drawn through them.

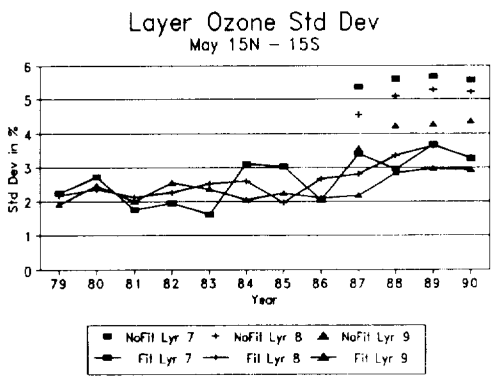

Figure 8: The same as above for layers 7,8, and 9.

There was a smaller improvement in the total ozone data. Since the total ozone is calculated using wavelength pairs, this partially compensated for the non-sync in the chopper wheel. The standard deviations in the zonal means improved slightly after using the corrected albedo data. Comparison of the SBUV data with the TOMS data, fig 9 and 10, does not show any bias introduced by using the corrected albedos in the non-sync period.

Conclusions

Using the smoothed photometer data to compensate for the non-synchronization between the chopper wheel and the counting electronics has improved the ozone data derived from the SBUV measurements.

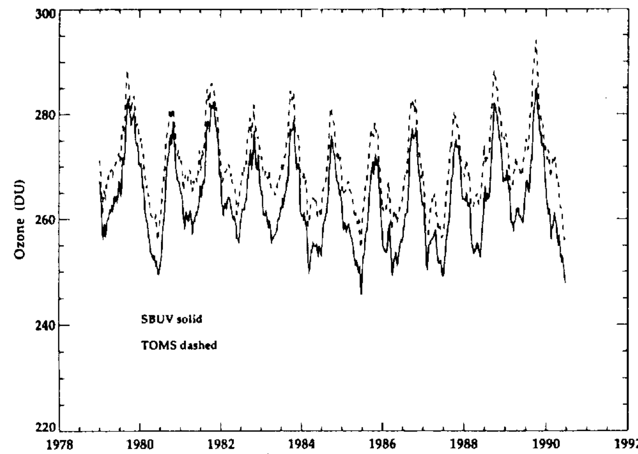

Figure 9: The weekly zonal average for TOMS and SBUV total ozone for the latitude band 20S to 10S. The TOMS is the dashed line and the SBUV is the solid line. The offset between the data sets is caused by initial calibration differences.

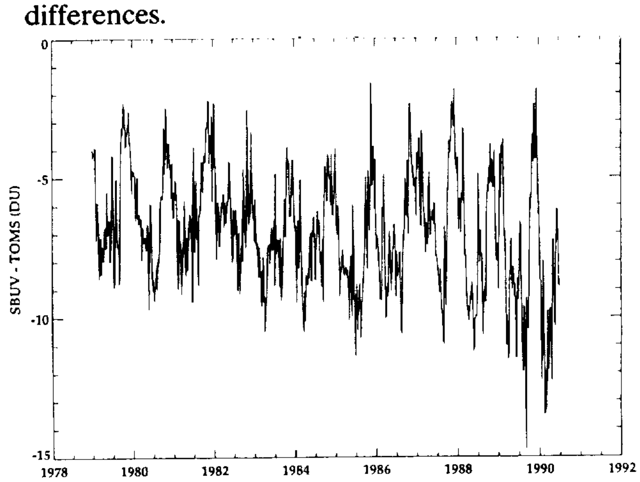

Figure 10: A time series of the difference between the SBUV and TOMS total ozone. Using the corrected albedos does not appear to have introduced a bias in the total ozone data.

Appendix 1

Instrument characteristics
Double Ebert-Fastie monochromator, 1 nm bandwidth
12 Wavelengths (nm): 339.8, 331.2, 317.5, 312.5, 305.8, 301.9, 297.5, 292.2, 287.6, 283.0, 273.5, 255.5
Photometer Channel 343 nm, 3 nm bandwidth
32 second measurement sequence
12 channels (339.8 to 255.5) measured in 18 seconds

Orbital Characteristics
Sun-synchronous Polar orbit 13-14 orbits/day
11.3° x 11.3° (200 km x 200 km) field of view
each orbit separated by 26°
footprint speed 6 km/sec