

**POST LAUNCH PERFORMANCE
OF THE
METEOR-3/TOMS INSTRUMENT**

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Abstract

The Meteor-3/TOMS instrument is the second in a series of Total Ozone Mapping Spectrometers (TOMS) following the 1978 launch of Nimbus-7/TOMS. TOMS instruments are designed to measure total ozone amounts over the entire earth on a daily basis, and have been the cornerstone of ozone trend monitoring. Consequently, calibration is a critical issue, and is receiving much attention on both instruments.

Performance and calibration data obtained by monitoring systems aboard the Meteor-3 instrument have been analyzed through the first full year of operation, and indicate that the instrument is performing quite well. A new system for monitoring instrument sensitivity employing multiple diffusers has been used successfully and is providing encouraging results. The 3-diffuser system has monitored changes in instrument sensitivity of a few percent despite decreases in diffuser reflectivity approaching 50 percent since launch.

Introduction

The Meteor-3/TOMS instrument was launched aboard a Soviet Meteor-3 spacecraft on August 15, 1991. The TOMS instruments are part of a class of ozone monitoring instruments which measure atmospheric albedo through the Backscatter Ultraviolet (BUV) technique (Klenk et al. 1982). As with other BUV instruments, M3/TOMS is in a polar orbit (82.5° inclination), though at the somewhat higher

altitude of 1200 km. Unlike other BUV instrument platforms, the orbital plane of the Meteor-3 spacecraft precesses relative to the sun-earth vector with a period of approximately 212 days. This rapid precession rate impacts the ability to monitor and calibrate the instrument, as well as having implications for ozone retrieval.

With the exception of its solar diffusers, the TOMS instrument optics are identical to those of its predecessor (N7/TOMS) aboard the Nimbus-7 spacecraft (Heath et al. 1975). While some of the electronics have been updated, major features such as the spectrometer design, wavelength channels, cross-track scanning, and field of view remain unchanged on the newer instrument. Three major calibration and monitoring functions are used aboard both instruments. Two of these, the wavelength and electronic calibration systems are completely unchanged on M3/TOMS. The principles of solar irradiance measurement are the same as on N7/TOMS but are functionally different with a change from one to three diffuser plates. Since this change represents a significant improvement over N7/TOMS for calibration of instrument sensitivity, and hence in the accuracy of ozone measurements, a more detailed discussion of the solar irradiance measurements will follow.

Wavelength Calibrations

The wavelength calibration system is designed to monitor the wavelength stability of the spectrophotometer. Entrance slits separate from those used for

ozone retrieval are used to sample light from a Hg lamp at 4 wavelengths near the 296.7 nm emission line. Changes in the relative signal levels measured at each wavelength are an indirect measure of a common shift in the band center of the ozone channels. Calibrations are made once per day and are capable of resolving day to day variations of $2 \cdot 10^{-4}$ nm. Overall variations as much as .04 nm, caused by thermally driven changes in the instrument housing or photomultiplier sensitivity, have been observed. Left uncorrected, the observed variations could cause as much as 1.5% error in derived ozone.

Diffuser Calibrations

The BUV class instruments determine ozone amounts by measuring the earth albedo at several wavelengths. The six TOMS wavelengths λ_i are nominally 312.5 nm, 317.5 nm, 331.2 nm, 339.8 nm, 360.0 nm, and 380.0 nm. The albedo at each wavelength is determined by the ratio I/F , where the earth radiances $I(\lambda_i)$ are measured during earth viewing mode and solar irradiances $F(\lambda_i)$ are measured during solar viewing mode. An important advantage of albedo measurement is that changes in instrument sensitivity and solar flux cancel when F is measured with sufficient frequency.

TOMS instruments utilize aluminum diffusers to fill the instrument's field of view during solar irradiance measurements. The diffuser is the only optical element which is not common to both earth and solar measurements so the albedo determination depends on accurate knowledge of the diffuser reflectivity. Experience has shown that reflectivity degrades with diffuser exposure, either to sunlight or to the space environment (Herman et al. 1990). While the N7/TOMS instrument has no mechanism for measuring diffuser reflectivity, subsequent SBUV/2 instruments have had measurement systems added based on an onboard Hg lamp. The dilemma faced with the N7/TOMS instrument is that of obtaining frequent solar measurements while minimizing the exposure of its single diffuser. The task of separating the diffuser from other instrument changes is difficult as well.

The method employed on the M3/TOMS instrument is that of the 3-diffuser system, similar to a system on the Solar Mesosphere Explorer (Rottman et al. 1982) but unique among the BUV instruments. The diffusers, referred to as *Cover*, *Working*, and *Reference*, are arranged as the sides of an equilateral triangle and mounted on a carousel so that they can be rotated into the instrument field of view on command. A given diffuser must be exposed during solar measurements, but is protected while another is being used. Thus the amount of exposure that each diffuser receives is varied such that the most infrequently measured undergoes little degradation while the other two can be measured as frequently as desired. As its name implies, the *Cover* diffuser is exposed constantly and is viewed roughly 13 times per day. The *Working* diffuser is viewed once per week and the *Reference* diffuser twice per 212 days. The reflectivity of the more frequently measured, and thus more degraded, diffusers are calibrated relative to the *Reference* by nearly simultaneous measurements of the solar flux. Thus at a given time t , $F(t) \propto$

$$S_c(t) \cdot \frac{R_c(t_0)}{R_c(t)} = S_w(t) \cdot \frac{R_w(t_0)}{R_w(t)} = S_r(t) \cdot \frac{R_r(t_0)}{R_r(t)}$$

where S represents the signal measured by the instrument with a given diffuser and R is its time dependent reflectivity. Integrated exposure amounts of the three diffusers are given in the table below.

Diffuser Exposure at One Year

	total exp. (hours)	equivalent solar exp. (hours)
Cover	8800	~ 750
Working	2.2	1.72
Reference	0.35	0.34

The ratio of the solar signals S to S_r on day 129 are shown in Figure 1 as a function of time since launch for each of the three diffusers. While only the shortest wavelength channel is shown, signals in the other channels are qualitatively the same. The rela-

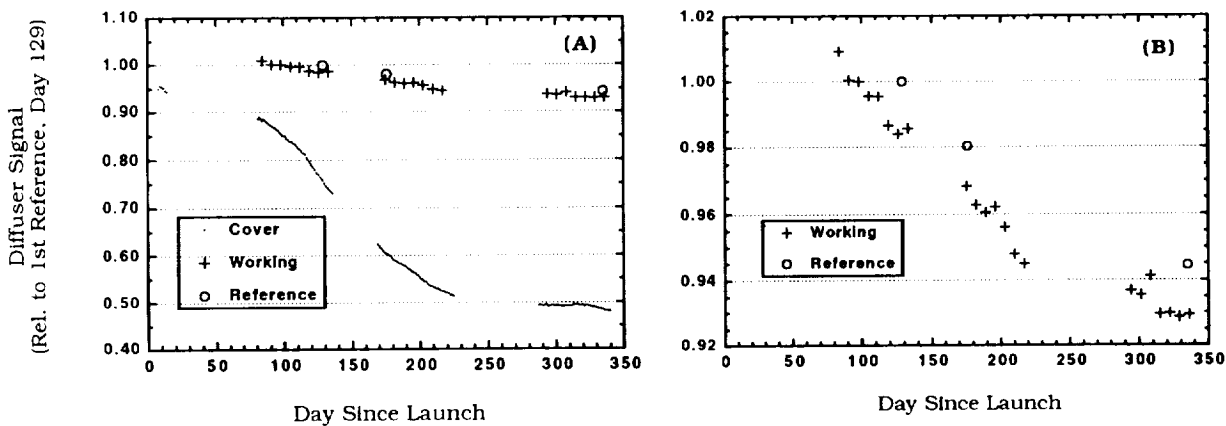


Figure 1 Diffuser signals measured during the first year relative to the *Reference* measurement of day 129; a) all three diffusers, b) *Working* and *Reference* diffusers alone.

tive frequency with which each diffuser is used is evident in the plot. Large gaps in the data occur during periods when the instrument cannot view the sun due to the orbital precession. The continuous exposure of the *Cover* diffuser has led to a significant drop in its associated signal level, while *Working* and *Reference* signals have remained relatively stable during the same time period. The degradation of the *Cover* diffuser relative to the *Working* diffuser, determined from the ratio S_c/S_w , is almost 50% by the end of the period shown in Figure 1(a). A plot of the ratios in each channel, shown in Figure 2, illustrates the strong wavelength dependence of *Cover* diffuser degradation.

A similar technique has been applied to determine *Working* diffuser degradation. Close agreement ($< 0.25\%$ change in S_w/S_r) between the three sets of coincident *Working* and *Reference* measurements seen in Figure 1 indicates little relative change between the two. This evidence supports the hypothesis that neither diffuser has undergone significant degradation. Nevertheless *Working* diffuser signals have dropped by about 8% since their first measurement in November, 1991. *Working* diffuser exposure is not sufficient to cause significant degradation, nor is the observed change wavelength dependent as with the *Cover* diffuser. These facts suggest the downward

slope seen in Figure 1 is a result of changes in instrument sensitivity. A drop in sensitivity affects solar irradiance and earth radiance measurements equally and so will not change the measured albedo I/F .

An area of concern is that the instrument lacks a calibration system which detects diffuser degradation unrelated to exposure. At present such degradation is indistinguishable from a decrease in instrument sensitivity. Designs for future TOMS instruments supplement the multi-diffuser system with an onboard Hg lamp to eliminate this ambiguity. If the 8% drop seen in Figure 1(b) is actually caused by such a degradation rather than a drop in instrument sensitivity, then the value of F will be incorrect. While such an error would not directly affect ozone retrieval because of the wavelength independence of the observed change, earth reflectivity derived from M3/TOMS measurements might be high by 10% over some areas of the globe. This error can indirectly influence the derived ozone amounts by as much as 2%. Independent studies of M3/TOMS radiances measured over Greenland and Antarctic ice indicate the instrument sensitivity has decreased by at least 8% during the first year of operation, thus reaffirming the relation between diffuser exposure and optical degradation.

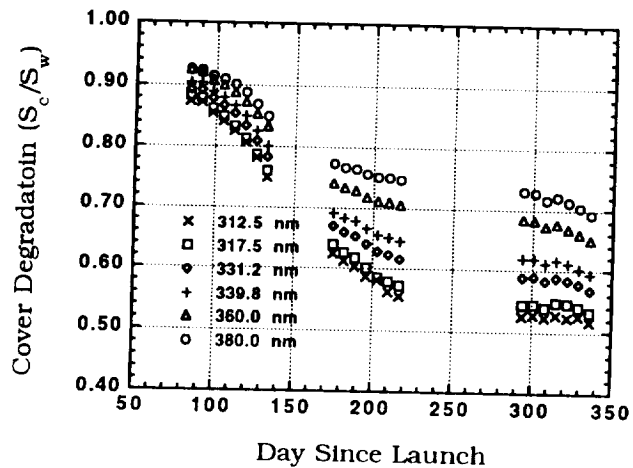


Figure 2 Cover diffuser reflectivity relative to Working diffuser, at each of the 6 TOMS channels.

Summary

Monitoring and calibration systems aboard Meteor-3/TOMS indicate that the instrument is operating normally and yielding science data comparable to those of the Nimbus-7/TOMS. The new diffuser calibration system is performing as expected and has shown itself to be robust against diffuser degradation. Separation of diffuser related changes from other instrument changes should be possible with greater accuracy than on Nimbus-7/TOMS. Pre-

liminary analysis of the solar irradiance data indicates that the most frequently exposed diffuser has degraded by as much as 50% and instrument sensitivity has dropped by at least 8%.

Acknowledgements

This work was performed under NASA contracts NAS5-29386, NAS5-31380, and NAS5-31755.

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