5.1. McMurdo Station (1/29/03 – 2/1/04)

The 2003/04 season at McMurdo Station is defined as the period between the site visits 1/23/03-1/29/03 and 2/2/04-2/11/04. The season opening and closing calibrations were performed on 1/27/03 and 2/2/04, respectively. Volume 13 solar data comprises the period 1/29/03 – 2/1/04. About 91% of the scheduled scans are part of the data set; approximately 6% are missing because of technical problems described in the following:

- The GPS, which is used for automatic time adjustment, failed to report the correct year after 8/4/03. From 8/5/03 onward, time-keeping was performed with a software application ("Tardis") that updates time via the Internet. This application has been successfully implemented at other sites. However, there is some evidence that the application was the cause for communication problems between the system control computer and peripheral electronics described in the next item. After extensive trouble shooting, the application was disabled on 12/19/03 and the time was adjusted manually. Between 12/19/03 and the end of the season time errors were larger than normal but never exceeded one minute.

- On several occasions between 8/30/03 and 12/19/03, the system control computer was not able to talk to a module ("Spectralink") that is controlling the stepper motor and amplifying the PMT signal. This problem lead to frequent losses of the monochromator's wavelength position, requiring manual wavelength adjustment by the system operator. Affected data were checked for wavelength shifts during preparation of final data and corrected if required, but some data were lost (see Section 5.1.4). The problem disappeared after the Internet time-server application was disabled.

- The system's UPS failed on 12/30/03 and was switched off. At the same time, several UPS systems of other instruments installed at Arrival Heights failed too, suggesting a common cause. With the UPS disabled, a power outages in January 2004 lead to data loss. The UPS was replaced during the site visit in February 2004.

- There are no PSP pyranometer data between start of the recording after Polar Night and the end of the season due to a defective preamplifier.

The Eppley PSP and TUVR instruments installed at McMurdo were replaced by identical instruments during the site visit in January 2003. The PSP and TUVR radiometers installed during the Volume 13 period were calibrated by Eppley Laboratory Inc. in October 2002. PSP solar data measured between Polar Night and the end of the season could not be used due a defective preamplifier. Data measured before this time compare well with data of previous years. TUVR data agree to within ±10% with historic data. We generally cannot confirm the calibrations provided by Eppley Laboratory Inc. and therefore advise data users to treat TUVR data as "uncalibrated," and use them for referential purposes only.

5.1.1. Irradiance Calibration

The site irradiance standards for the 2003/04 McMurdo season were the lamps 200W005, 200W019, and M-543. Lamp M-764 was used as traveling standard. Its calibration was established by Optronic Laboratories in March 2001. Lamps 200W005 and M-543 were recalibrated by comparison with M-764 using scans performed during the site visits in 2001 and 2002 (see Section 4.2.1.5 for details of the procedure). Lamp 200W019 has an Optronics Laboratories certificate from September 1998, and was not recalibrated.

Figure 5.1.1 shows the Volume 13 season opening calibrations performed on 1/27/03. All standards agree at the ±1.0% level. A similar comparison for measurements performed at the end of the season is shown in

Figure 5.1.2. Two additional comparisons between M-543, 200W005, and 200W019 performed mid-season (on 4/26/03 and 8/20/03) indicate a similar level of agreement.

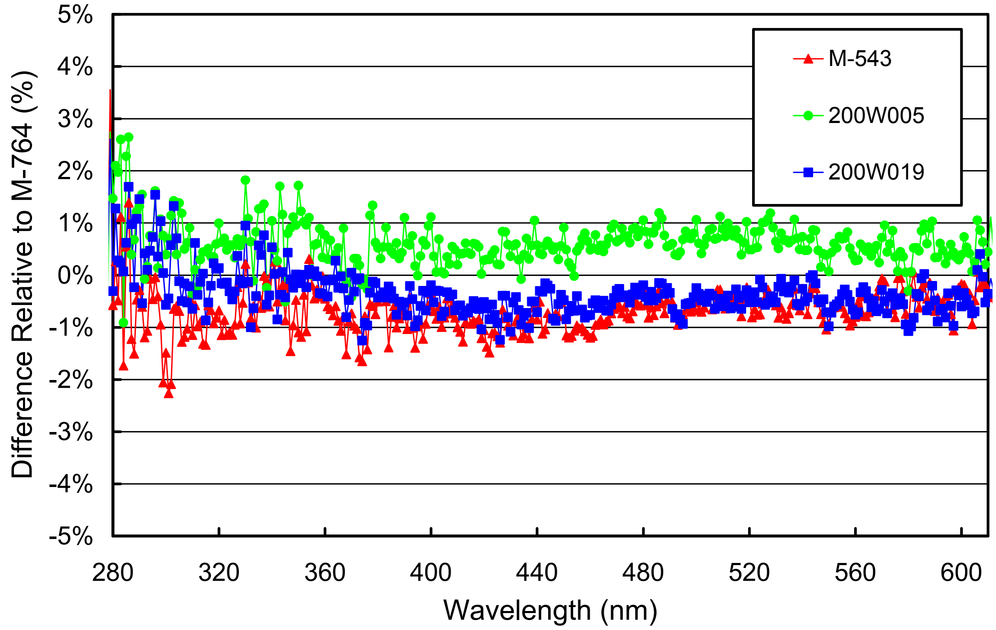

Figure 5.1.1. *Comparison of McMurdo lamps M-543, 200W005, and 200W019 with the BSI traveling standard M-764 at the beginning of the season (1/27/03).*

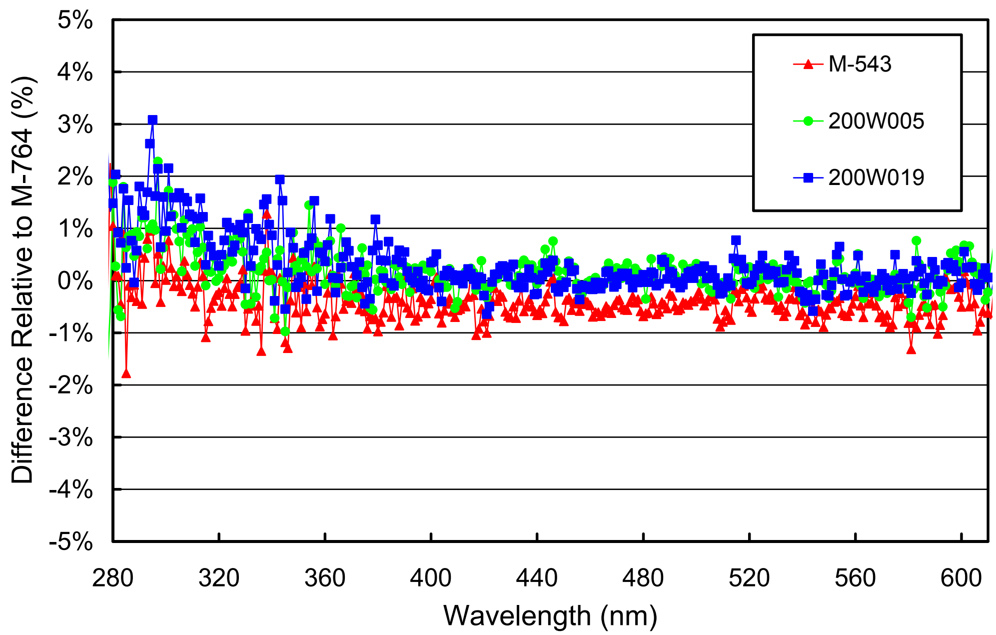

Figure 5.1.2. *Comparison of McMurdo lamps M-543, 200W005, and 200W019 with the BSI traveling standard M-764 at the end of the season (2/2/04).*

5.1.2. Instrument Stability

The stability of the spectroradiometer over time is primarily monitored with bi-weekly calibrations utilizing the site irradiance standards and daily response scans of the internal irradiance reference lamp. The stability of this lamp is monitored with the TSI sensor, which is independent from possible monochromator and PMT drifts. By logging the PMT currents at several wavelengths during response scans, changes in monochromator throughput and PMT sensitivity can be detected.

Figure 5.1.3 shows the changes in TSI readings and PMT currents at 300 and 400 nm, derived from the daily response scans. TSI measurements indicate that the internal reference lamp became brighter by 4.5% during the season. PMT currents increased by approximately 3% during the first two weeks, decreased by 3.5% during the following 5 months and increased by 6-7% in September and October. A similar pattern has been observed during previous seasons; its actual cause is unknown. In addition, PMT currents at both wavelengths dropped by 2-3% between 11/21/03 and 11/22/03. The reason of this change could not be identified. Associated drifts in published solar data are smaller than 1%, as daily scans of the internal lamp are not only used to monitor variations but also to correct for changes.

The season was broken in five calibration periods to correct for the increase of irradiance of the internal lamp. In each of these periods, a different irradiance function was assigned to this lamp following the procedure described in Section 4.2.1.2. Figure 5.1.4 shows the ratios of those functions relative to the function applied in the first period (1/29/03–4/17/03). The calibration functions for Periods 1-3 deviate by less than ±2%. However calibrations performed before 9/30/03 differ by 2-4% from calibrations conducted after 10/21/03. As there were no absolute scans performed between 9/30/03 and 10/21/03, it was not possible to determine whether the calibration has changed abruptly or gradually. We therefore calculated the average of the calibrations performed in Periods 3 and 4, and applied this average to the period 10/5/03–10/15/03.

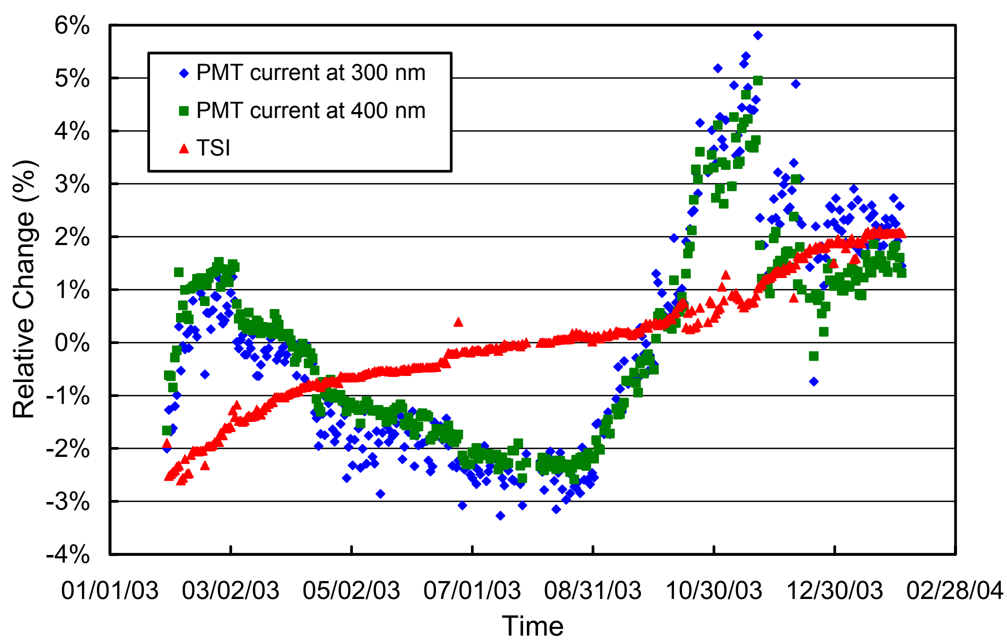

Figure 5.1.3. *Time-series of PMT current at 300 and 400 nm, and TSI signal during measurements of the internal irradiance reference lamp during the McMurdo 2003/04 season. The data is normalized to the average value of the whole season.*

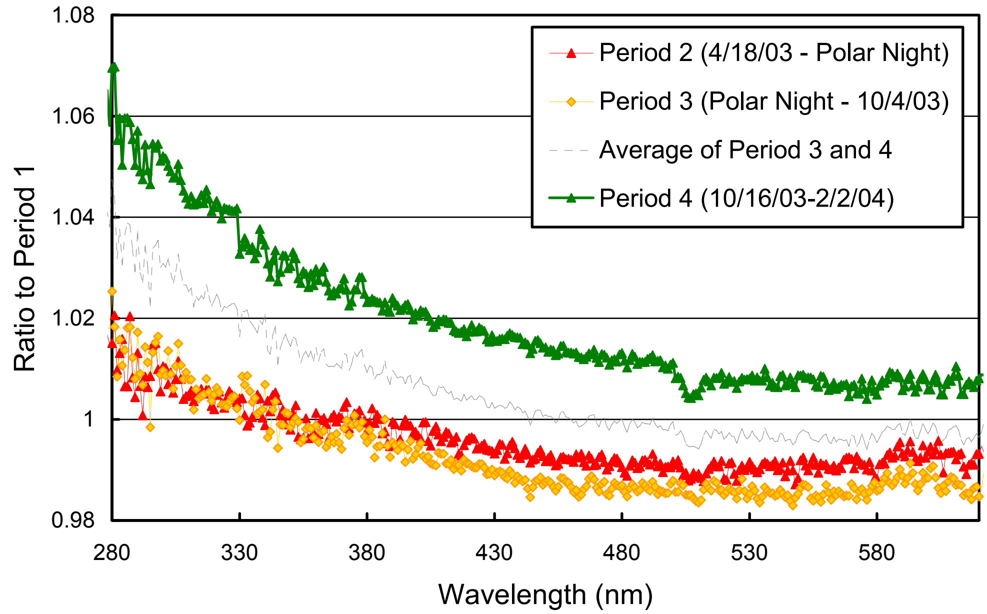

Figure 5.1.4 *Ratio of irradiance assigned to the internal reference lamp to the Period 1, 1/29/03–4/17/03.*

Figure 5.1.5 presents the ratios of the standard deviations and average spectra, calculated from the individual absolute scans of each period. These ratios are useful for estimating the variability of the calibrations in each period. The variability is typically less than 1% for wavelengths above 300 nm in all periods, indicating good stability in every period.

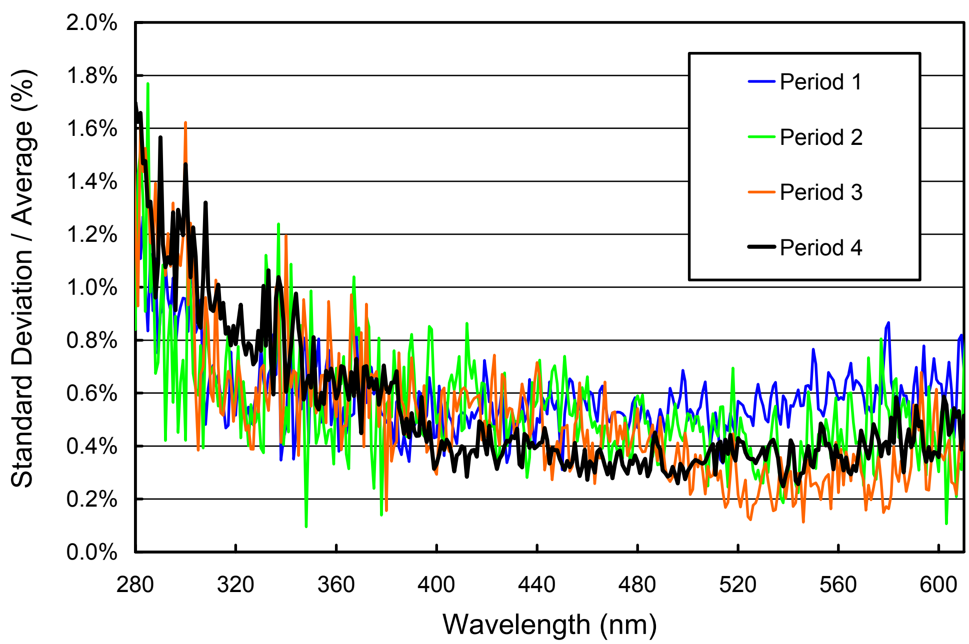

Figure 5.1.5. *Ratio of standard deviation and average calculated from the absolute calibration scans.*

5.1.3. Wavelength Calibration

Wavelength stability of the system was monitored with the internal mercury lamp. Information from the daily wavelength scans was used to homogenize the data set by correcting day-to-day fluctuations in the wavelength offset. After this step, there may still be a deviation from the correct wavelength scale, but this bias should ideally be the same for all days. Figure 5.1.6 shows the differences in the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 384 pairs of scans have been evaluated. For 83% of the days, the offset change is smaller than ±0.025 nm; for 92% of the days it is smaller than ±0.055 nm. There was a comparatively large number of events when the offset-difference exceeded ± 0.1 nm. These cases were caused by the systems lock-ups related to problems indicated above. The wavelength mapping of solar data from these days was reviewed and either appropriate adjustments were made or the data were not published.

After the data was corrected for day-to-day wavelength fluctuations, the wavelength-dependent bias between this homogenized data set and the correct wavelength scale was determined with the Fraunhofer-correlation method, as described in Section 4.2.2.2. The correction function is shown in Figure 5.1.7. After the data was wavelength corrected using this function, the wavelength accuracy was again tested with the Fraunhofer method. The results are shown in Figure 5.1.8 for four UV wavelengths. The residual shifts are typically smaller than ±0.1 nm, except for the 10/25/03, when the shift of all wavelengths exceeded 0.1 nm. In October, the wavelength setting had to be adjusted frequently and in a few cases, such as the one on 10/25/03, the wavelength setting could not be determined unambiguously. However, the wavelength should not be shifted by more than 0.15 nm in any period. There is more scatter at 310 nm shortly before and after polar night, because of the small solar irradiance levels that prevail during this part of the year. The wavelength stability is not worse during this time; yet the correction algorithm is less precise.

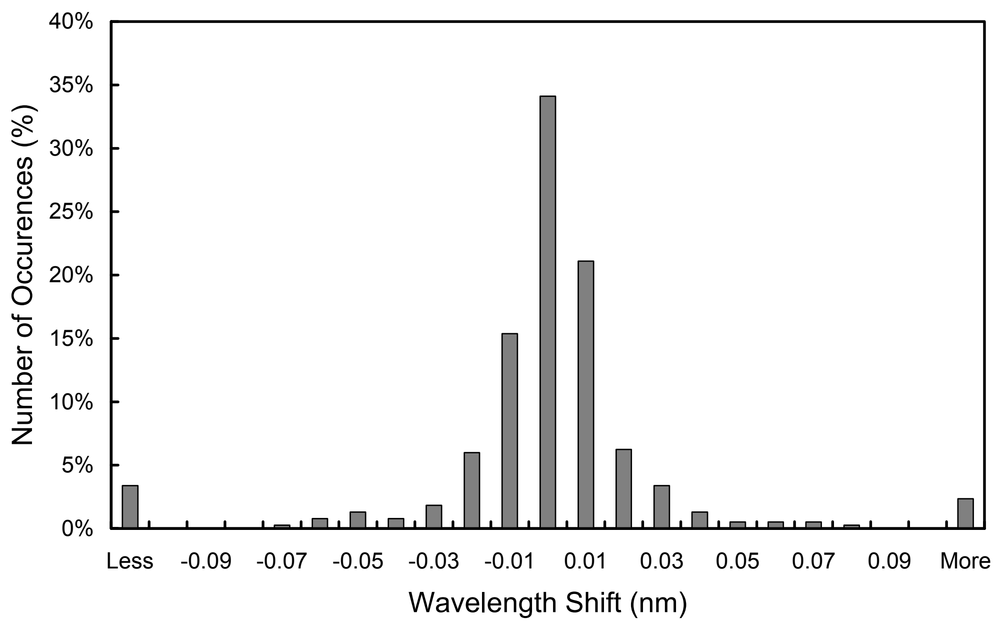

Figure 5.1.6. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. The 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more" means shifts larger than 0.105 nm.*

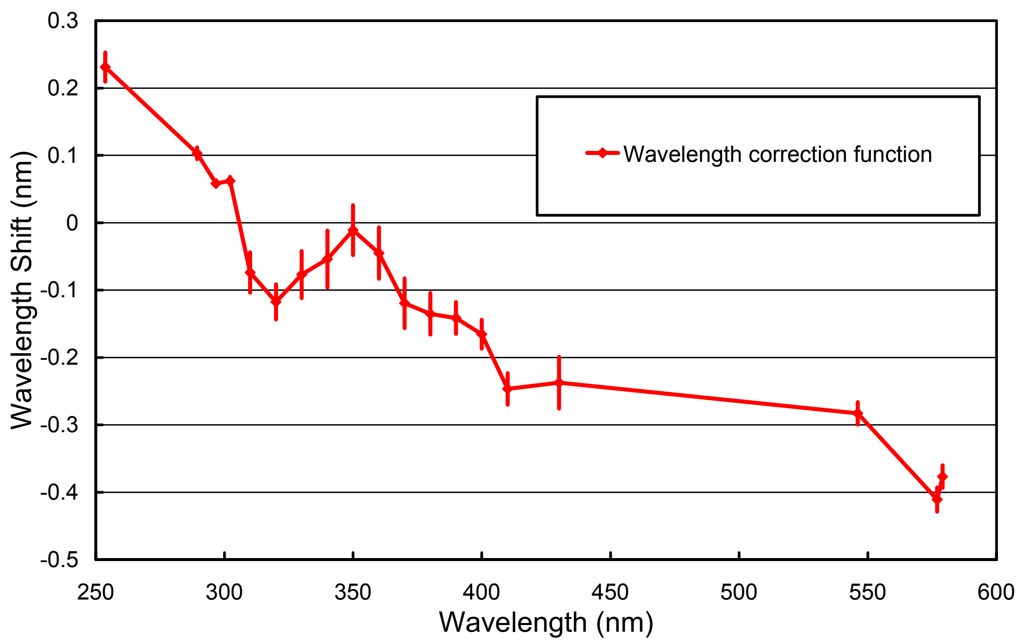

Figure 5.1.7. *Monochromator non-linearity correction functions for McMurdo 2003/04 data. The function was calculated with the Fraunhofer-correlation method.*

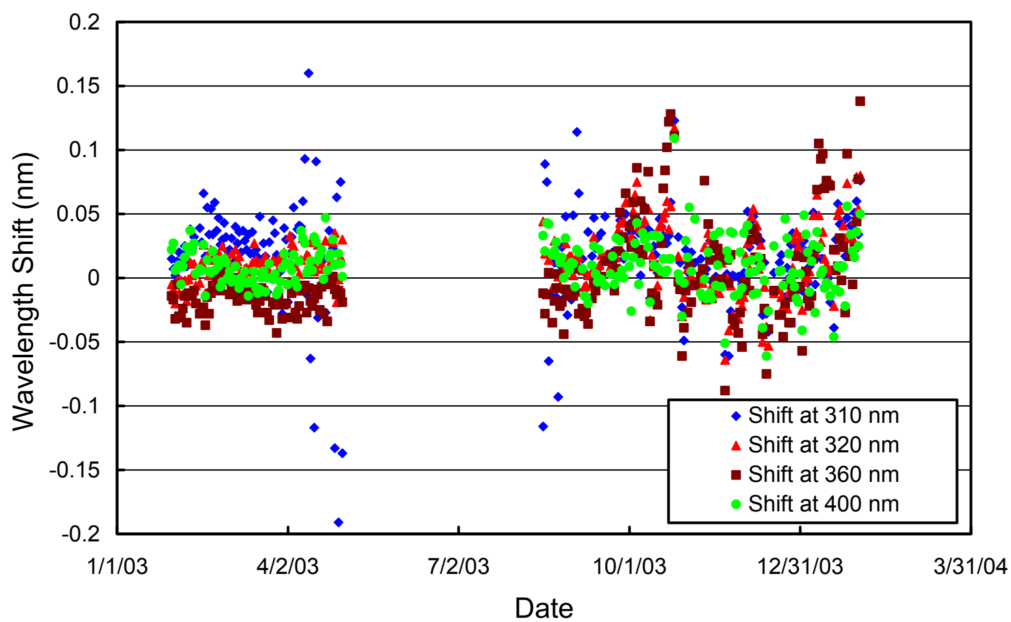

Figure 5.1.8. *Check of the wavelength accuracy of the final data at four wavelengths by means of Fraunhofer correlation. The noontime measurement has been evaluated for each day of the season. No correlation data is available during the polar night.*

Data from the external mercury scans do not have a direct influence on data products. They are, however, an important part of instrument characterization. Figure 5.1.9 illustrates the difference between internal and external mercury scans collected during both site visits. The wavelength scale of the figure is the same as applied during solar measurements. The peak of the external scans agrees well with the nominal wavelength of 296.73 nm, whereas the peak of the internal scans is shifted about 0.09 nm to shorter wavelengths. External scans have a bandwidth of about 1.02 nm FWHM. The bandwidth of the internal scan is 0.75 nm. Since external scans have the same light path as solar measurements, they more realistically represent the monochromator bandpass relevant for solar scans. The scans at start and end of the season are very consistent.

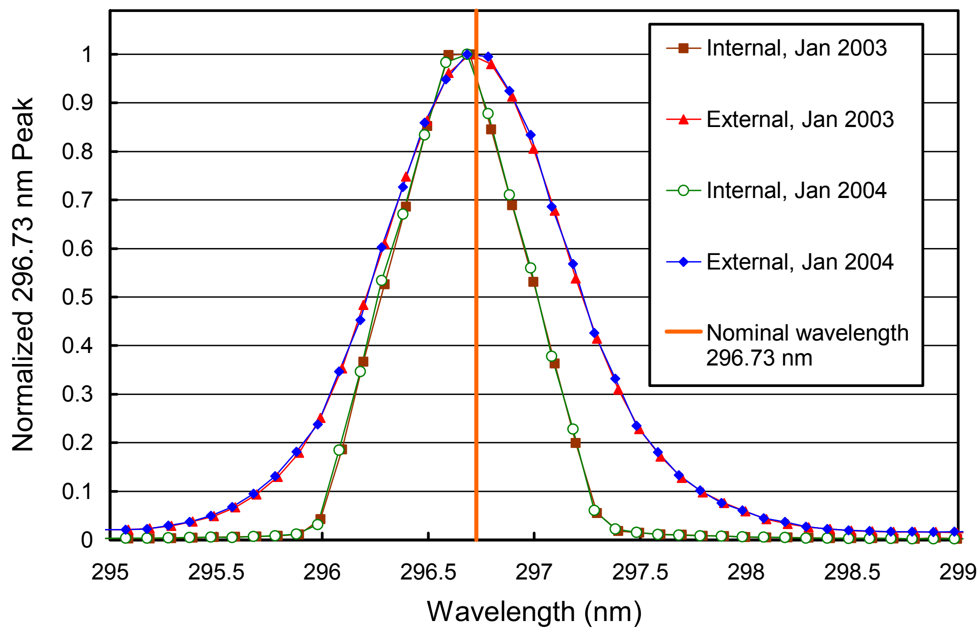

Figure 5.1.9 *The 296.73 mercury line as registered by the PMT from external and internal sources. The wavelength scale is the same as applied for solar measurements, i.e., it is based on a combination of internal scans and the Fraunhofer-correlation method. It is assumed that the wavelength registration of the monochromator did not shift between internal and external scans, which were close in time.*

5.1.4. Missing Data

A total of 17201 scans are part of the published McMurdo Volume 13 dataset. These are 91% of the scans scheduled. Of all missing data scans, 93, 319, and 322 were superseded by absolute, wavelength, and response scans, respectively. Approximately 6% of all scans were missed due to technical problems.

The most significant problem was related to communication errors between the system control computer and the module ("Spectralink") that controls the stepper motor and amplifies the PMT signal. This problem lead either to system "lock-ups" or to losses of the monochromator's wavelength position, requiring manual wavelength adjustment by the system operator. A total of 676 solar scans was lost. Table 5.1 lists the missing scans by date.

The monochromator's wavelength setting was off by several nanometers during three periods and the associated solar data could not be salvaged. The following days were affected: 9/18/03 - 9/20/03 (loss of 68 scans after replacement of monochromator wavelength indicator), 12/14//03 – 12/16/03 (loss of 223 scans following power outage without UPS backup), and 1/25/04 – 1/26/04 (loss of 120 scans following power outage without UPS backup). In addition, 40 scans from several days throughout the year are missing for various reasons, such as software updates.

Table 5.1. Number of missing scans related to communication problem by date. 26 additional scans are missing on various days between 8/15/03 and 12/19/03.

September		October		November		December	
Date	Missing	Date	Missing	Date	Missing	Date	Missing
09/04/03	31	10/10/03	23	11/05/03	40	12/14/03	6
09/05/03	20	10/23/03	45	11/06/03	96	12/17/03	12
09/09/03	19	10/24/03	53	11/07/03	10	12/18/03	4
09/10/03	21	10/25/03	52			12/18/03	46
09/16/03	7	10/26/03	45			12/18/03	5
09/17/03	18	10/28/03	3			12/18/03	36
09/18/03	3					12/19/03	7
09/28/03	8						
09/29/03	35						
09/30/03	5						

5.1.5. GUV Data

During the site visit in 2002, a Biospherical Instruments GUV-511 moderate-bandwidth filter radiometer was installed in close proximity to the collector of the SUV-100. The GUV-511 instrument provides measurements in four approximately 10 nm wide UV bands centered at 305, 320, 340, and 380 nm, as well as photosynthetically active radiation (PAR). From data recorded at these wavelength, total column ozone, spectral integrals, and dose rates for a large number of action spectra is calculated and made available in near real-time via the website http://www.biospherical.com/nsf/login/update.asp. Details about calibration and calculation of data products are at http://www.biospherical.com/nsf/presentations/SPIE_paper_5156-23_Bernhard.pdf . In addition to providing data via the Internet, the radiometer is also used to quality control SUV-100 measurements. For example, fluctuations in the ratio of measurements of the two instruments may indicate a problem in either of the two data sets, prompting for further examination.

Figure 5.1.10. shows a comparison of GUV-511 and SUV-100 erythemal irradiance based on final Volume 13 data. For SZA smaller than 80°, 98.6% of the data agree to within ±10% with each other. There is a short period around 12/1/03 when the agreement was worse due to heavy snow fall.

The agreement for some data products (e.g. DNA damaging variation) may be worse than that for erythema due to principal limitations in calculating dose-rates from the four GUV-511 channels when the Sun is low and when the data product in question is heavily weighted toward wavelengths below 310 nm. We therefore advise data users to use SUV-100 rather than GUV-511 data when possible, in particular for low-Sun conditions.

Note that a new data set of SUV-100 data, named "Version 2" is currently in preparation (see http://www.biospherical.com/nsf/Version2/Version2.asp). Version 2 data are corrected for the cosine error of the SUV-100 spectroradiometer. Version 2 erythemal data are approximately 6% higher than the Version 0 data that are discussed in this report. GUV measurements were calibrated both against cosine error corrected and uncorrected SUV-100 data, and both data sets were published. Preliminary GUV data made available via the website http://www.biospherical.com/nsf/login/update.asp are based on the calibration with the cosine corrected SUV-100 data set, and are therefore approximately 6% higher than data plotted in Figure 5.1.10.

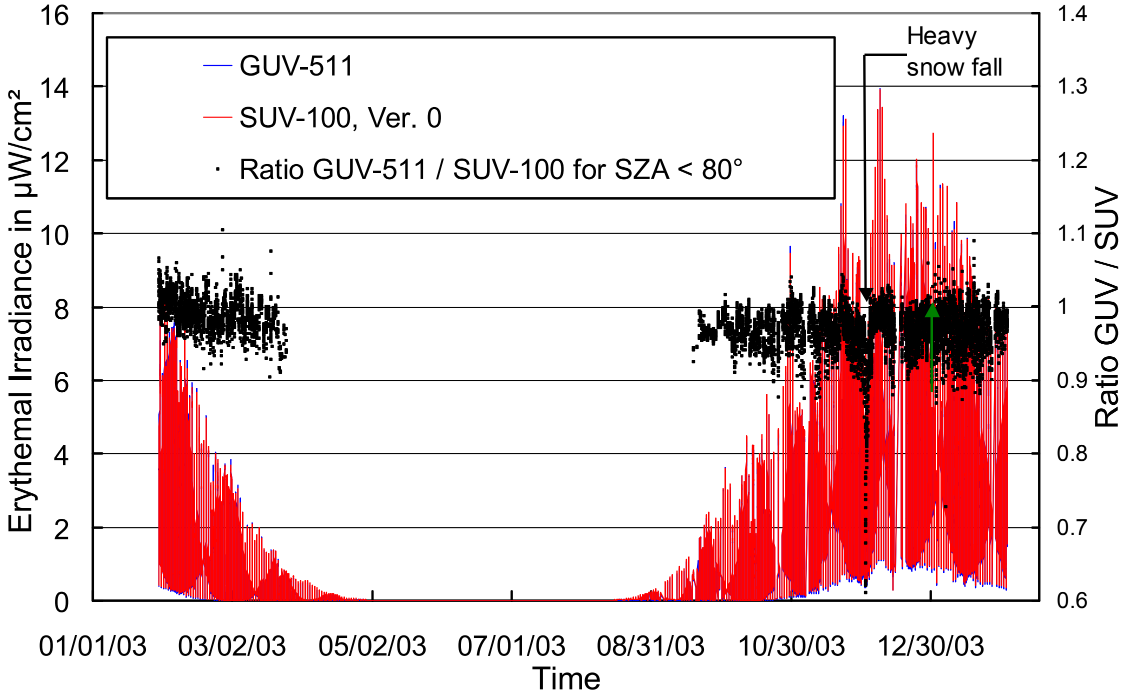

Figure 5.1.10. Comparison of erythemal irradiance measured by the SUV-100 spectroradiometer and the GUV-511 radiometer. All data is based on "Version 0" (cosine-error uncorrected) data, see text.

Figure 5.1.11 shows a comparison of total ozone measurements from the GUV-511 and NASA/TOMS Earth Probe satellite (Version 7). GUV-511 ozone values were calculated as described in http://www.biospherical.com/nsf/presentations/SPIE_paper_5156-23_Bernhard.pdf. TOMS ozone values are on average 4% higher than GUV-511 data. This is in agreement with previous observations showing that TOMS Version 7 data are biased high at high latitudes. This problem will be corrected in the soon-to-be-released TOMS Version 8 data set. For SZA larger than 85°, GUV-541 data become unreliable and should not be used.

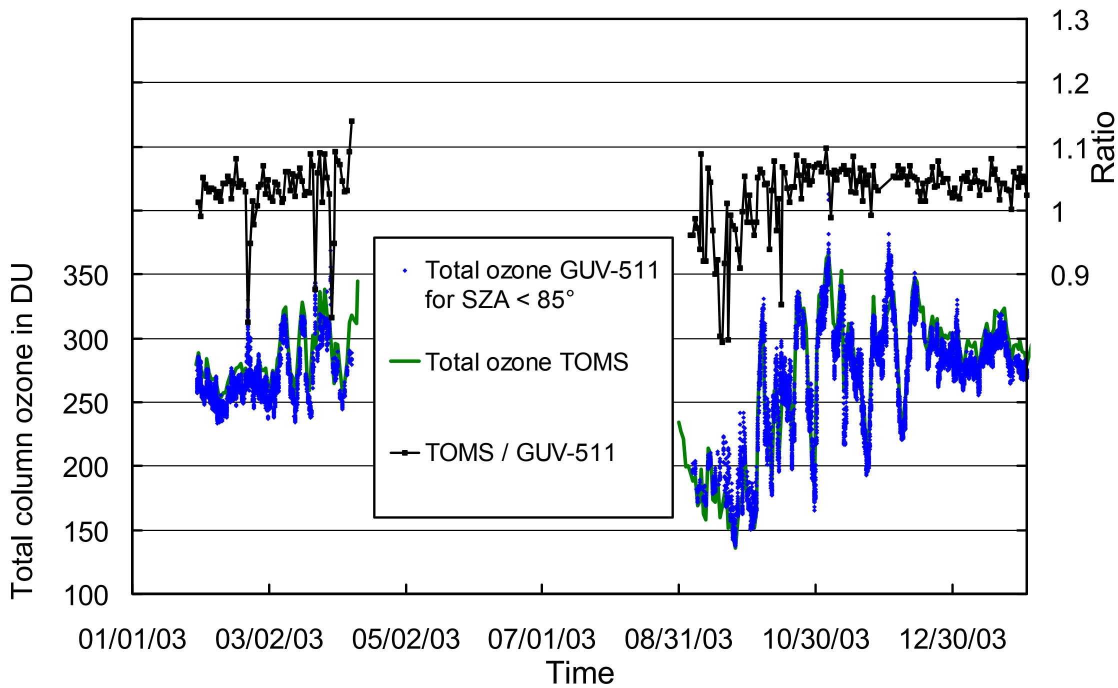

Figure 5.1.11. *Comparison of total column ozone measurements from GUV-511 and NASA/TOMS Earth Probe satellite. GUV-511 measurements are plotted in 15 minute intervals. For calculating the ratio of both data sets, only GUV-511 measurements coincident with the TOMS overpass data were evaluated.*