5.2. McMurdo Station, Antarctica

McMurdo Station is located on the southern tip of Ross Island (77°51'S, 166°40'E), and has had a long history in Antarctic exploration. It is the largest field station in Antarctica, accommodating up to 1200 People in summer and 250 in winter. There is a large laboratory facility (Crary Lab) supporting a wide range of scientific projects. McMurdo Station is operated year-round but is typically accessible between the months of October and February, with the exception of a short series of flights in early September or late August ("WinFly"). The spectroradiometer at McMurdo Station was upgraded to a Version "C" system in 1991, and is located in the roof of the facility at Arrival Heights, in the hills above the main base. The system received subsequent computer and LAN upgrades along with minor enhancements. The facility at Arrival Heights is not continuously manned, but is visited regularly every one to three days. The system is operated by ASA personnel that have been trained by BSI staff.

The data are originally recorded onto both a 120-MB removable hard disk media and a hard disk drive internal to the system control computer. Data archiving is automated. The system control computer, utilizing the Windows NT operating system and the McMurdo Local Area Network (LAN), is setup as a File Transfer Protocol (FTP) server. This allows for data to be directly transferred by BSI staff from the system control computer via the Internet gateway at McMurdo. Files can also be transferred as e-mail attachments, or FTP'd by the operator.

The following figures and table display characteristics regarding the location and conditions at McMurdo Station.

Figure 5.2.1. *Installation at the corner of the Arrival Heights laboratory. A stairway provides access for calibrations and inspections. The McMurdo Ice Shelf is in the background*

Table 5.2.1. McMurdo Station (Arrival Heights): bearings of obstructions to the instrument's field-of-view.

Object Name	Bearing (degrees)	Horizon (degrees)
Observation Hill	163.5	0.83
Mt. Erebus	6-22	5.7
Second Crater	24-39	5.5
Unnamed Bump	41-52	3.7
Mt. Terror	53-55	2.9
Star Lake	57-115	2.2
Crater Hill	120-136	3.6
Mt. Discovery	207-211	3.1
Mt. Lister	246-257	1.8
Anemometer Mast	295-296	21.7

***Notes*:** Elevation is measured in degrees above the Arrival Heights instrument location. Instrument is at 183 meters above sea level. Sightings were obtained from the site operator, Joe Longo, during the January 1995 site visit.

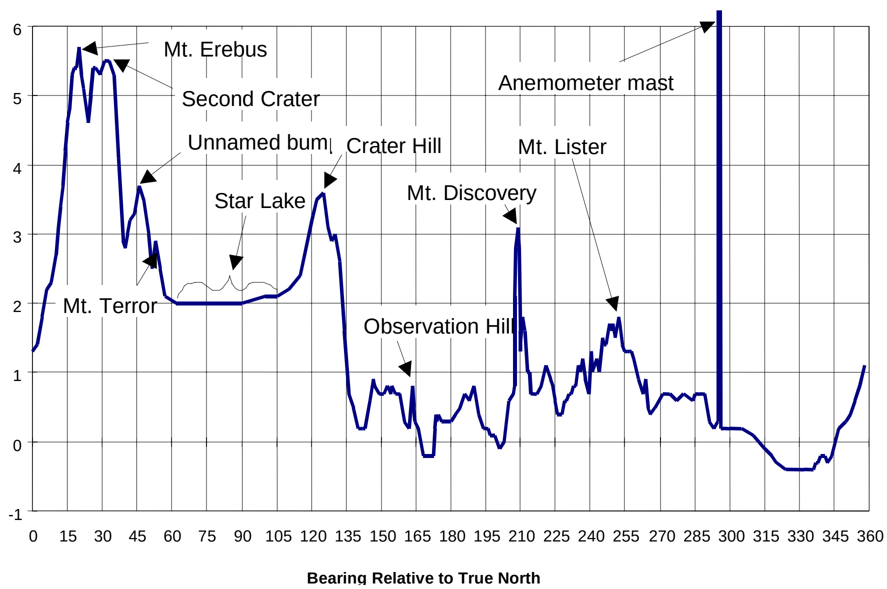

Figure 5.2.2. *This chart displays the obstructions in the collector's field-of-view at Arrival Heights. Units are in degrees above the horizon vs. bearing relative to True North.*

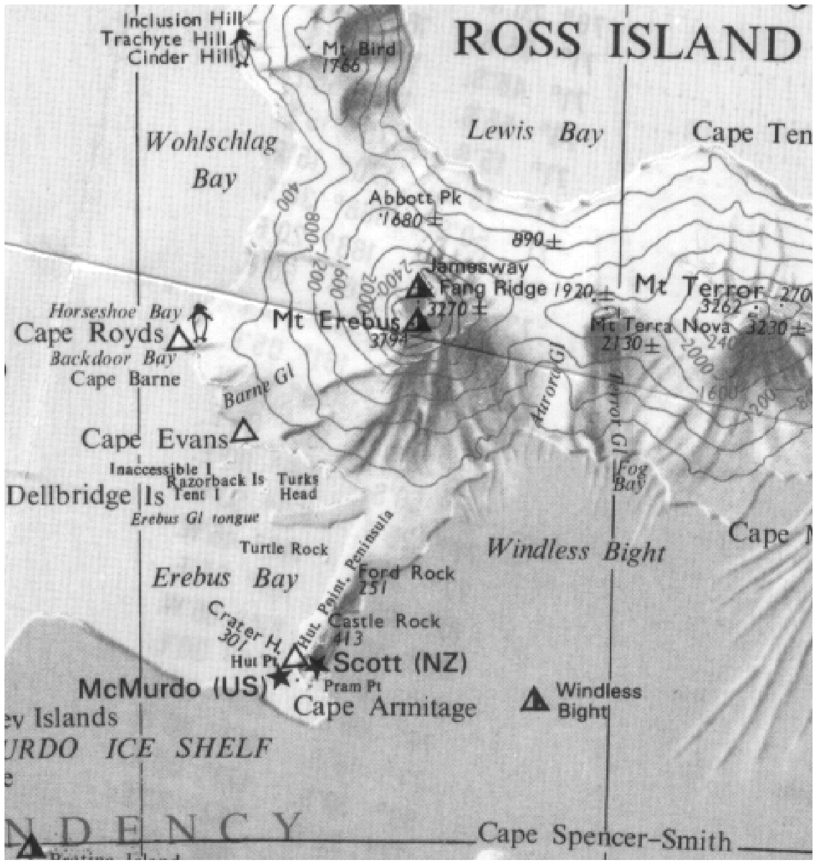

Figure 5.2.3. *Map of the local region around McMurdo (lower left corner).*

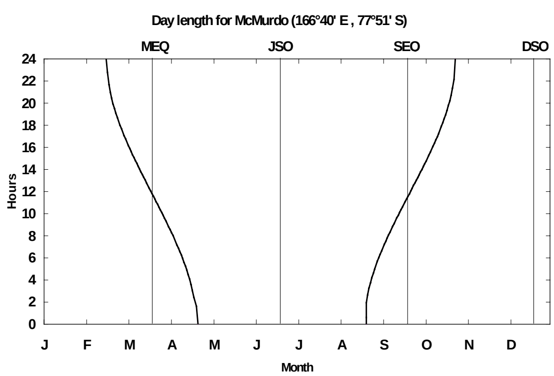

Figure 5.2.4. *Day length plot for McMurdo. (MEQ = March equinox, JSO = June solstice, SEQ = September equinox, DSO = December solstice).*

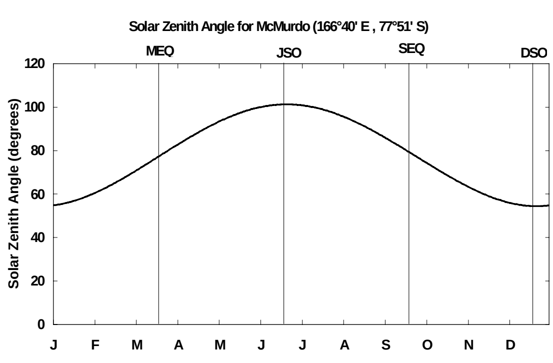

Figure 5.2.5. *Plot of noontime solar zenith angle in degrees.*

5.2.1. Weather Observations

Weather observations for McMurdo Station (WMO station number 89664) were obtained from the National Climatic Data Center (NCDC). The data are in a format described in Appendix A7. of this report. This file, MCMURDO.CSV, can be found in the \WEATHER subdirectory on the CD-ROM 7.0.a.

5.2.2 Ozone Observations

Table 5.2.2. TOMS ozone averages and minima for McMurdo, September 1 – December 31.

	TOMS												TOVS		
	Nimbus 7			Meteor 3			Adeos			Earth Probe					
Year	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**	**Avg**	**Min**	**Date**
1988	340.0	208	9/22/88												
1989	267.9	167	9/24/89												
1990	248.0	149	10/9/90												
1991	289.4	148	10/11/91	289.6	151	10/11/91									
1992	270.0	162	9/28/92	268.2	168	9/27/92, 9/28/92									
1993				249.7	111	9/29/93									
1994				260.0	128	10/3/94							255.1	128.5	10/23/94
1995													225.8	124	10/23/95
1996							277.0	150	10/5/96	262.5	150	10/1/96	232.6	138	10/6/96
1997										241.4	138.4	09/26/97			
1998										215.7	141.4	09/22/98			

Note: 1996 TOMS/Adeos data is only partially available; actual data starts on 9/11/96. 1998 TOMS/Earth Probe data is not available after 12/12/98. The average was therefore calculated from the period 9/1/98 – 12/12/98.

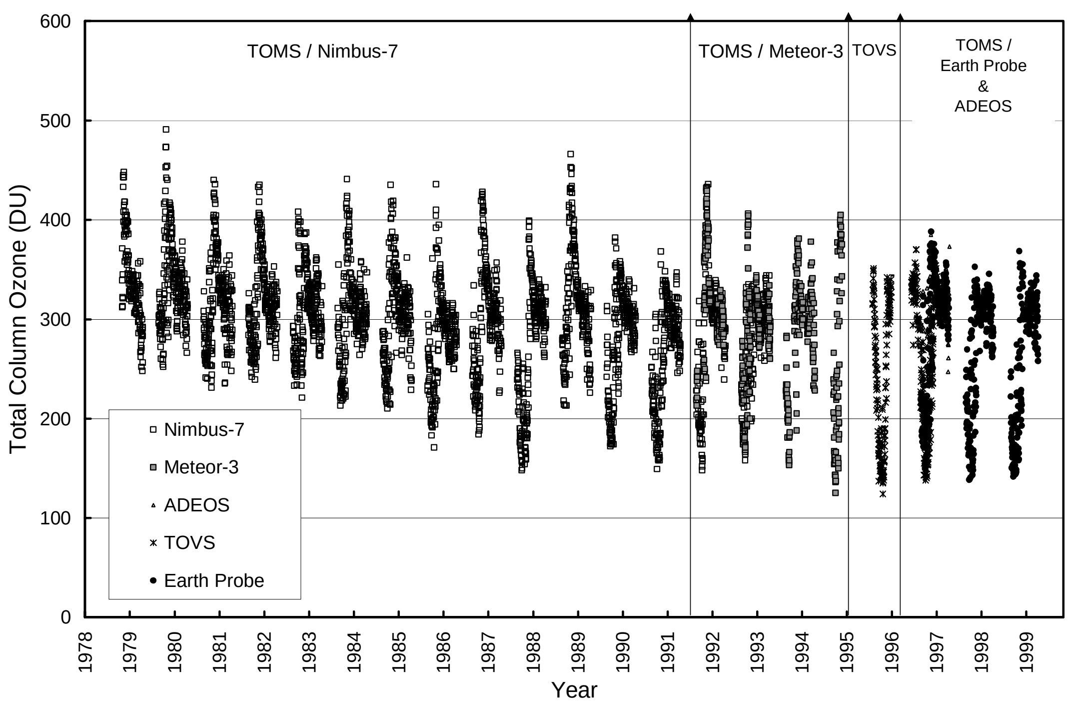

Figure 5.2.6. *Time record of total column ozone from TOMS and TOVS data at McMurdo. The downtrend attributed to ozone depletion can be seen clearly. Note the difference in the minimum ozone column observed in the 1970s and 1990s.*

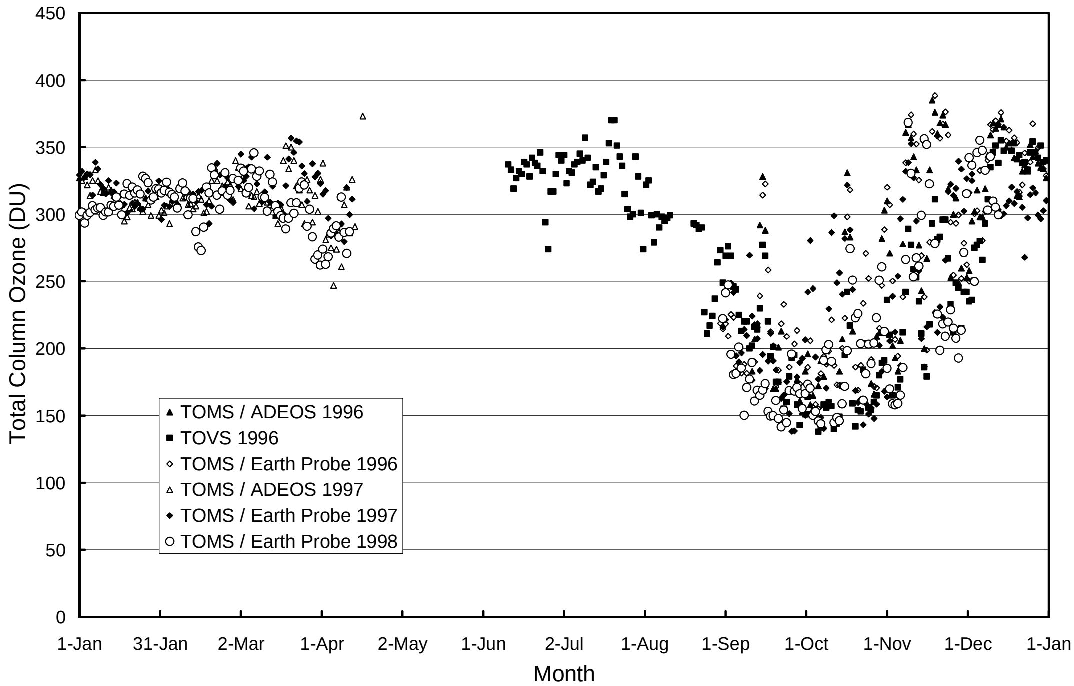

Figure 5.2.7. *Seasonal variation of ozone from TOMS and TOVS data at McMurdo. The decrease in ozone values in October is clearly apparent. The data gap is the Austral winter.*

5.2.3. McMurdo Station 1/11/97 – 1/18/98

The season-opening site visit at McMurdo was split in to two parts. In the first period, 1/11/97 – 1/15/97, the instrument was serviced, and on days 2/4/97 and 2/5/97 the season opening calibrations were performed. The site visit at South Pole took place between the two periods. The season closing visit took place between 1/14/98 and 1/18/98. Solar data is available for the period 1/18/97 – 1/13/98. There is a gap in the data between 1/26/97 and 2/9/97, preceding and succeeding the "second" season opening site visit. In this period, system components had to be temporarily removed to service the South Pole instrument. During the remaining time, the system operated normally. In the first months of the season, however, the sensitivity of the instrument was set too high leading to saturation in all response scans between 1/15/97 and 3/27/97. Fortunately, data scans were not affected and the response scans were repaired. The accuracy of solar data was only reduced by ±1%.

5.2.3.1. Stability in the Wavelength Domain

As described in Section 3, a new method to determine and correct systematic errors of the wavelength setting was implemented for the Volume 7 data. Wavelength *stability* of the system, however, was monitored with the internal Mercury lamp, as in previous seasons. Information from the daily wavelength scans was used to homogenize the data set by correcting day-to-day fluctuations of 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 5.2.8 shows the differences in the wavelength offset of the 296.73-nm mercury line between two consecutive wavelength scans. In total, 241 scans have been evaluated. The daily wavelength scans during the Polar night are not included since these measurements do not impact the data. For 85.5% of the days, the change in offset is smaller than ±0.025 nm; for 97.5% of the days the shift is smaller than ±0.055 nm.

Seven scans have an offset-difference larger than ± 0.095 nm, caused either by a manual adjustment of the offset or a large gap (e.g., the polar night) between the wavelength scans.

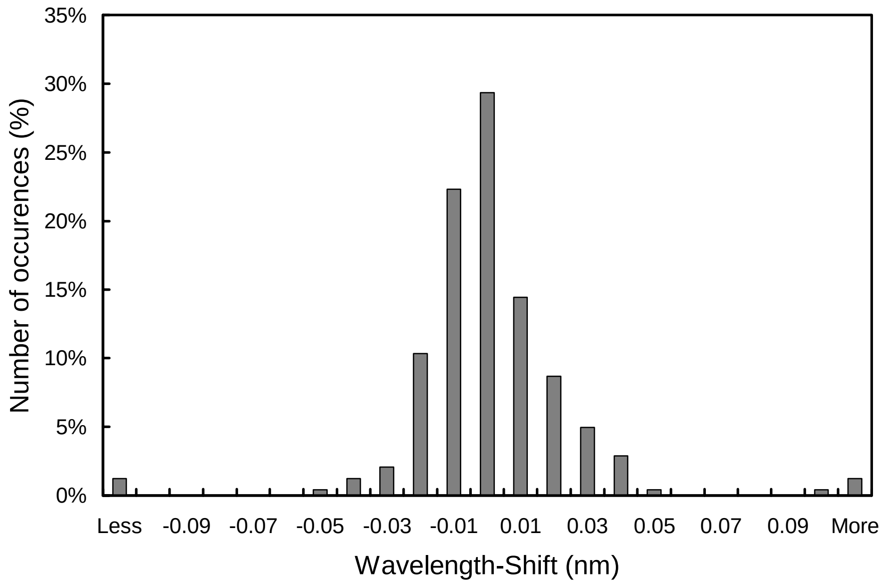

Figure 5.2.8. *Differences in the measured position of the 296.73 nm Mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. Thus the 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more" means shifts larger than 0.105 nm.*

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 3. The thick line in Figure 5.2.9 shows the resulting correction function that was applied to the Volume 7 McMurdo data. The wavelength-dependence of the function is caused by non-linearities of the monochromator drive. In order to demonstrate the difference between the result of the new Fraunhofer-correlation method and the method that had been applied historically, Figure 5.2.9 also includes a correction function that was calculated with the "old" method, i.e., the function is based on internal wavelength scans only. The average difference between both approaches is 0.146 nm. As explained in Section 3, the different light paths for internal wavelength scans and solar measurements cause this bias.

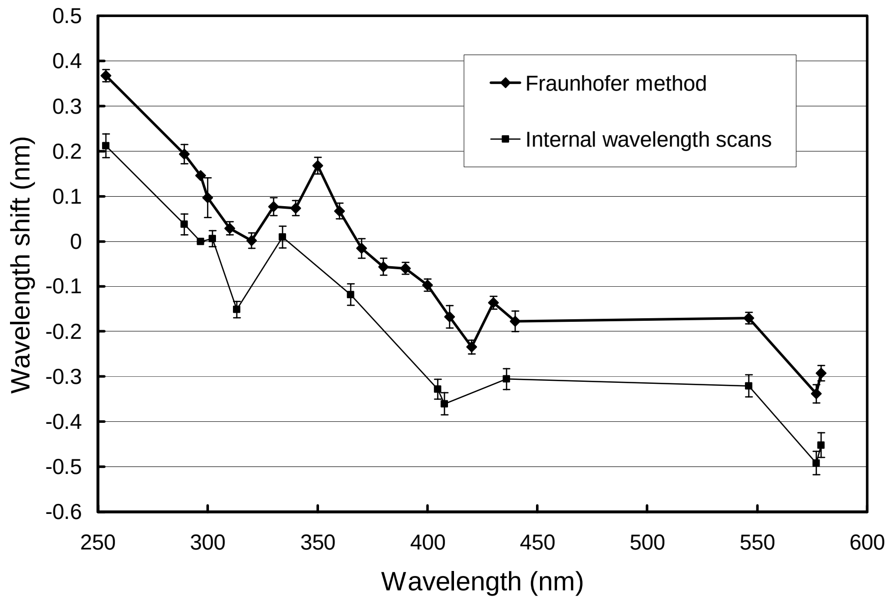

Figure 5.2.9. *Functions expressing the monochromator non-linearity for McMurdo. Thick line: Function calculated with the Fraunhofer-correlation method. This function was applied to correct the McMurdo Volume 7 data. Thin line: Function calculated with the method that was historically applied. The offset between both methods is 0.146 nm. Both functions represent average wavelength shifts for the 1997/98 season. The error bars give the 1 σ standard deviation of the wavelength shifts.*

After the data was wavelength corrected using the shift-function described above, the wavelength accuracy was tested again with the Fraunhofer method. The result is shown in Figure 5.2.10. At 310 nm, the wavelength shift for noontime measurements is smaller than ±0.05 nm when the SZA is smaller than 83°. The actual wavelength uncertainty may be a little larger because of wavelength fluctuations of about ±0.02 nm during a day and possible systematic errors of the Fraunhofer correlation method (see Section 3). The shifts for other wavelengths in the UV have a very similar pattern to the shift at 310 nm presented in Figure 5.2.10.

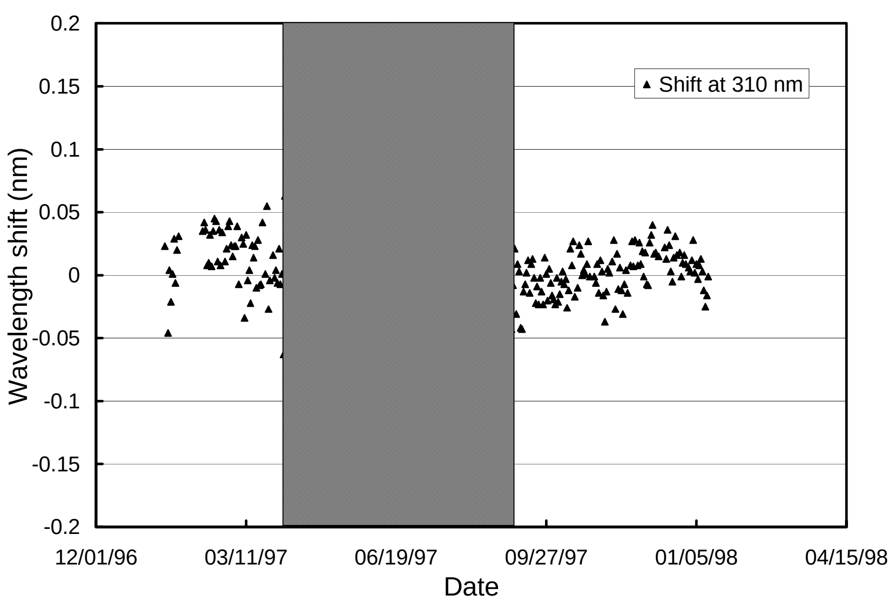

Figure 5.2.10. *Check of the wavelength accuracy of the final data by means of Fraunhofer correlation. For each day of the season the noontime measurement at 310 nm has been evaluated. Outside the shaded*

area, the shift is smaller than ±0.05 nm for all days. Inside the shaded area, the SZA of noontime measurements is larger than 83°. At these low solar elevations, the radiation levels at 310 nm are too low to gain a good correlation with the Sun's Fraunhofer lines. Outliers in this region are therefore caused by the algorithm rather then actual wavelength deviations of the system. During the Polar night a Fraunhofer-correlation is not possible.

Although the data from the external Mercury scans do not have a direct influence on the data products, they are an important part of instrument characterization. Figure 5.2.11 illustrates the difference between internal and external Mercury scans collected during both site visits.

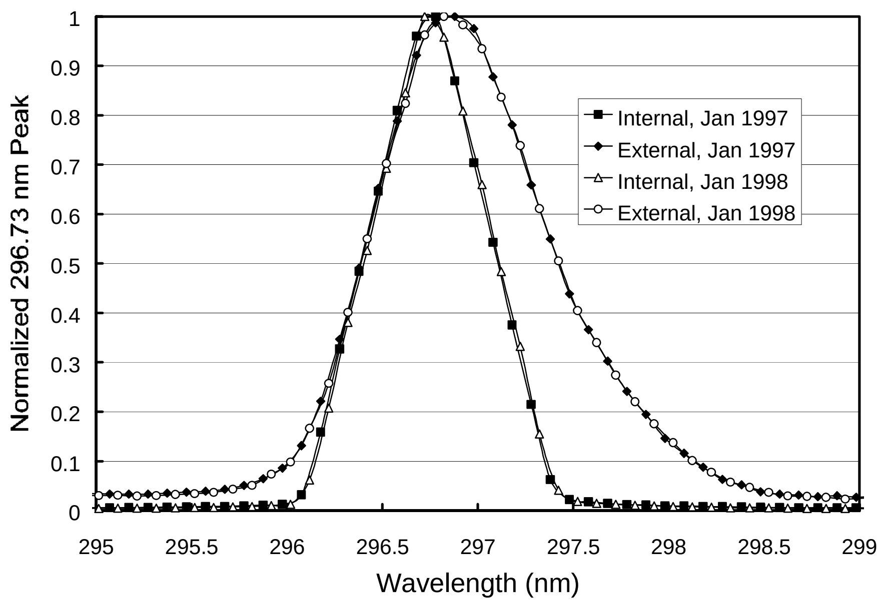

Figure 5.2.11. *The 296.73 mercury spectral line as registered by the PMT from external and internal source.*

External scans have a bandwidth of about 1.04 nm FWHM, whereas the bandwidth of the internal scan is only 0.72 nm. In addition, the peak of external scans is shifted by about 0.16 nm towards longer wavelengths, compared to the internal peak. This is very consistent with the mean difference of the results of both wavelength correction methods depicted in Figure 5.2.9 Since external scans have the same light path as solar measurements they more realistically represent the bandpass of the monochromator. The scans at the start and end of the season are very consistent, as can be seen from Figure 5.2.11.

5.2.3.2. Responsivity Stability

The stability of the spectroradiometer's responsivity over time was monitored with the following parameters:

- Measurements of the Total Scene Irradiance (TSI) filtered-photodiode sensor during response lamp scans
- Photomultiplier Tube (PMT) current at several wavelengths during response lamp scans
- Bi-weekly calibrations with 200-Watt irradiance standards

Note that the TSI sensor is completely independent from possible monochromator and PMT drifts, whereas the PMT current is affected by all system parts, including response lamp, monochromator, and PMT, and is also sensitive to temperature changes and high voltage applied. PMT current therefore also provides valuable insight into the possible drifts of these components.

Figure 5.2.12 shows the PMT current at 300 and 400 nm and the TSI behavior during the 1997/98 McMurdo season. All data is normalized to the averages of all measurements.

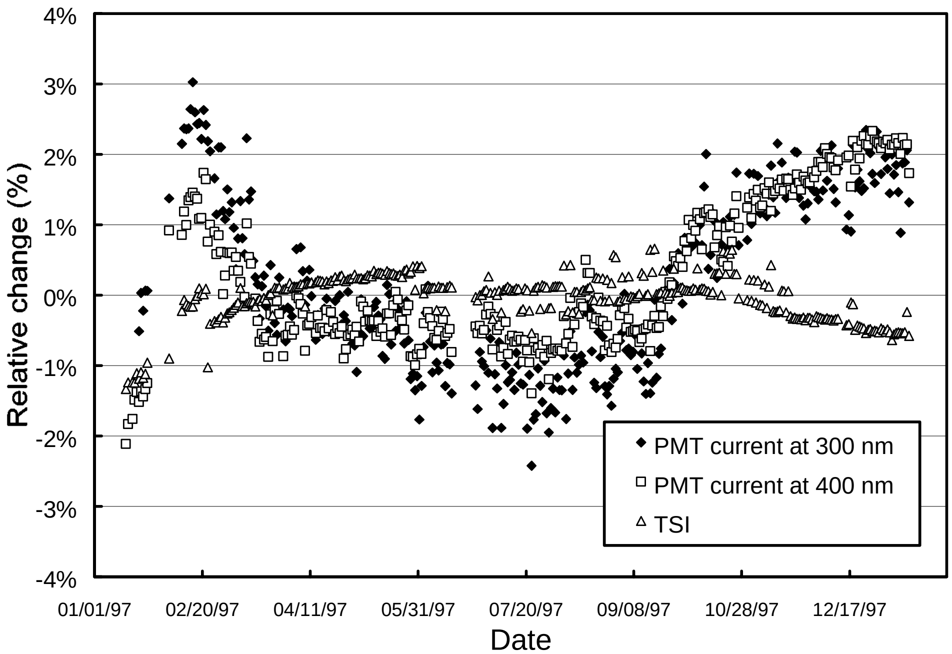

Figure 5.2.12. *Time-series of PMT current at 300 and 400 nm and TSI signal during measurements of the response lamp in the whole McMurdo 1997/98 season. The data is normalized to the average of the whole season.*

The TSI readings are stable to within ±1% throughout the whole season indicating that the response lamp was very stable. The PMT currents at 300 and 400 nm varied to within ±2%. Thus the responsivity of the instrument changed slightly more and in the opposite direction as the irradiance from the response lamp. This is corrected, however, through the daily response scans.

Because of the extraordinary stability of the response scan, the same “mean-irradiance” was assigned to the response lamp throughout the whole Volume 7 season. From all 200-W calibrations with the lamps 200W005, M-764 and M-874, which took place in the season, irradiance spectra of the response lamp were calculated and the mean-irradiance was derived by averaging over these spectra. (For more details about the definition of the “mean-irradiance”, see Section 3). In addition to the average, the standard deviation was derived from the individual spectra. Figure 5.2.13 shows the ratios standard deviations / average. Although calibrations during the whole season contributed to this plot the standard deviation is only about 1% of the average for wavelengths above 350 nm. Towards the short-wave UV-B, the standard deviation increases, as can be expected.

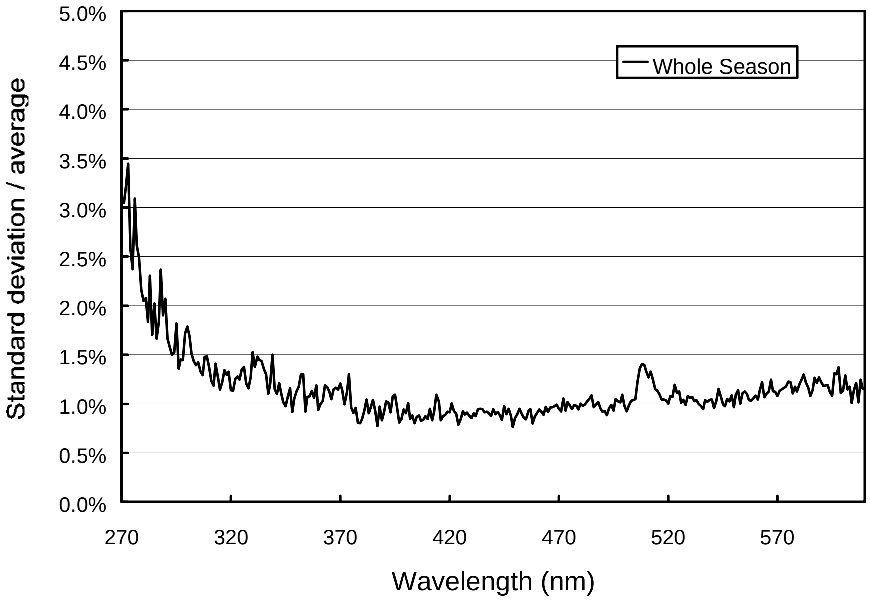

Figure 5.2.13. *Ratio of standard deviation and average calculated from all absolute calibration during the Volume 7 McMurdo season. See text for details.*

5.2.3.3. Lamp Intercomparison

The site standards for the Volume 7 McMurdo season were the lamps M543, M-764, and 200W005. Lamp M543 does not have a calibration from a standards laboratory (e.g., Optronic Laboratories). Because of the stability of the response lamp we declined to calibrate the lamp on-site, as was done at most of the other sites, and did not use the lamp for the calibration of the solar data. Lamps M-764 and 200W005 have Optronic Laboratories calibrations from 1992 and 1996, respectively. M-764 had already been the site standard in previous seasons; 200W005 is a new lamp.

Figure 5.2.14 shows the results of the season-opening calibrations, when the lamps M-764 and 200W005 were compared with the traveling standard M-874, which was calibrated by Optronic Laboratories in 1995. In the UV-A and visible, the calibrations of both sites standards are about 1-2% different from the calibration of M-874. At 300 nm, the difference of 200W005 and M-874 is about –4%, whereas the ratio M-764/M-874 is quite constant over the whole spectral range.

A second Optronic Laboratories calibrations from 1998 exists for M-874. The 1998 irradiance values are approximately 2% higher than the values from 1995. If the 1998 calibration had been used in Figure 5.2.14 the curves would move down by 2%, worsening the agreement.

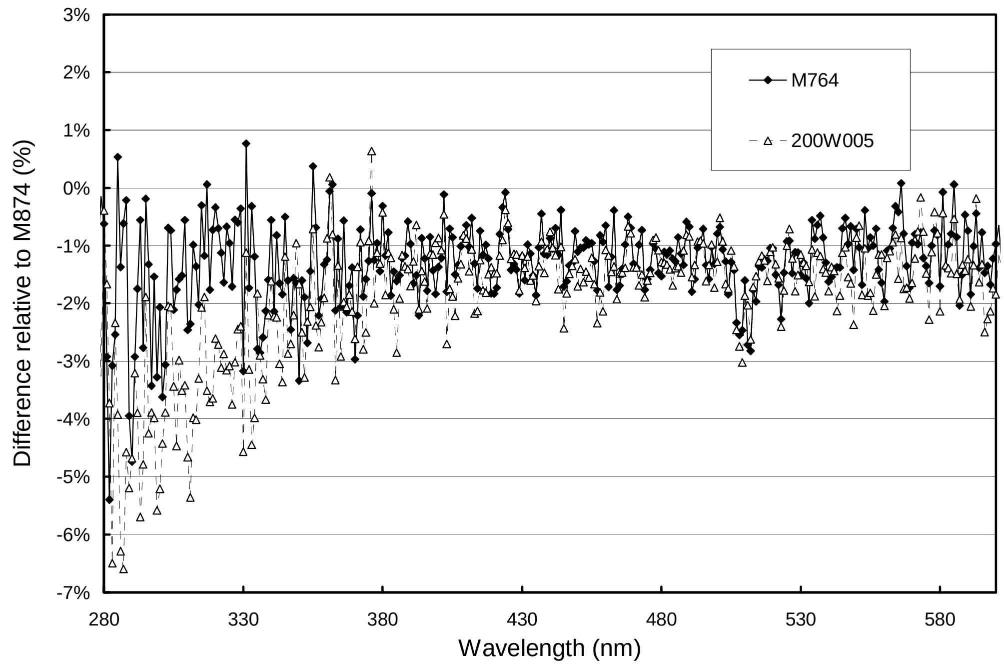

Figure 5.2.14. *Result of season opening calibrations, McMurdo, 2/4/97: Comparison of McMurdo lamps M-764 and 200W005 with the traveling standard M-874.*

Figure 5.2.15 is similar to Figure 5.2.14 but shows the season-closing, rather than opening, calibrations. The difference between M-764 and the traveling standard M-874 is very consistent for both calibration events. The curve for M-764 is 1% lower than M-874 throughout the spectrum. Compared to the season opening calibration, lamp 200W005 appears to have changed by 1.5 to 2%. A change of this magnitude is in the uncertainty range of lamp comparisons. The differences in the UV-B, UV-A and visible were more consistent at the season’s end.

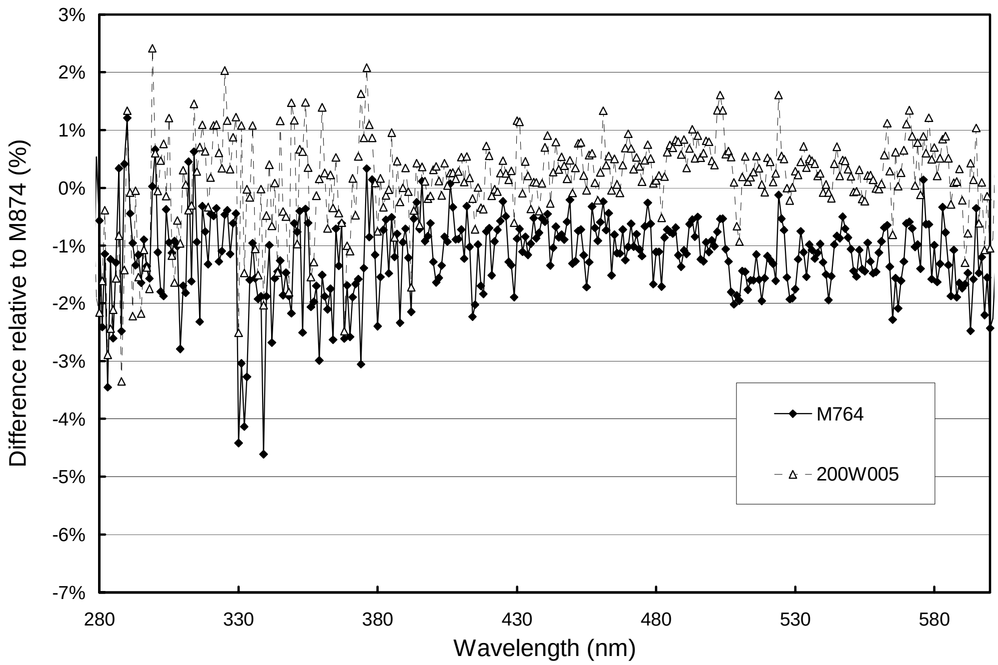

Figure 5.2.15. *Result of season closing calibrations McMurdo, 1/14/98: Comparison of McMurdo lamps M-764 and 200W005 with the traveling standard M-874.*

5.2.3.4. Missing Data

A total of 14446 scans with SZA smaller than 92° were scheduled to be measured in the McMurdo Volume 7 season, between 1/18/97 and 1/13/98. One scan per hour was measured until 9/1/97, as in previous seasons. No scans between 4/29/97 and 8/4/98 are included in Volume 7 because of the Polar Night. From 9/2/97 onwards, a scan rate of 4 scans per hour was scheduled. This caused a substantial increase in the total number of scans compared to previous seasons. A total of 13406 scans, 92.8% of the scans scheduled, were actually measured, and 13129 scans (90.9%) are included in Volume 7. Between 1/26/97 and 2/9/97, 715 (4.9%) data scans were lost because of the following reasons:

- Between 1/26/97 and 2/3/97 system components were shipped to South Pole to service the instrument there;
- Between 2/4/97 and2/5/97 the second season opening site visit took place; and
- Between 2/6/97 and 2/9/97 the data was stored in a format incompatible with the evaluation software.

A total of 395 data scans were superceded by either response or wavelength scans. Since McMurdo has 24 hours of sunlight per day in austral summer, a loss of some data scans cannot be avoided. Finally, approximately 140 data scans were superseded by absolute calibrations performed during the day.

Only 33 scans of all data scans measured were found to be defective and were therefore not included in Volume 7. Twenty two scans on 12/9/97 were lost because of a hard disk write problem and eight data scans on 3/28/97 could not be matched with a response scan because of incompatible high voltage settings.