5.6. Barrow, Alaska, USA

The Barrow installation is located on Alaska's North Slope at the edge of the Arctic Ocean in the city of Barrow. The instrument is located in the UIC-NARL (Ukpeagvik Inupiat Corporation - [formerly] Naval Arctic Research Laboratory) facility. Barrow is also a research site of the Atmospheric Radiation Measurement (ARM) program.

As at other sites, data are originally recorded onto both a 120-MB removable hard disk media and a hard disk drive internal to the system control computer. Archiving is automated. The system control computer, utilizing the Windows NT® operating system, is setup as a File Transfer Protocol (FTP) and Remote Access (RAS) server. With a modem and dedicated phone line in the lab, data files are directly downloaded from the system control computer by BSI staff.

Normal calibrations and instrument maintenance are conducted by Dan Endres and Malcolm Gaylord from the nearby NOAA/CMDL facility. The Barrow system is probably the most autonomously operating SUV-100 in the network.

Figure 5.6.1. *Roof installation at Barrow during the polar night (left). Note ice buildup on auxiliary sensors (right), and that the collector of the SUV-100, which is heated, remains free of snow, frost, and ice. Same installation during the day (right).*

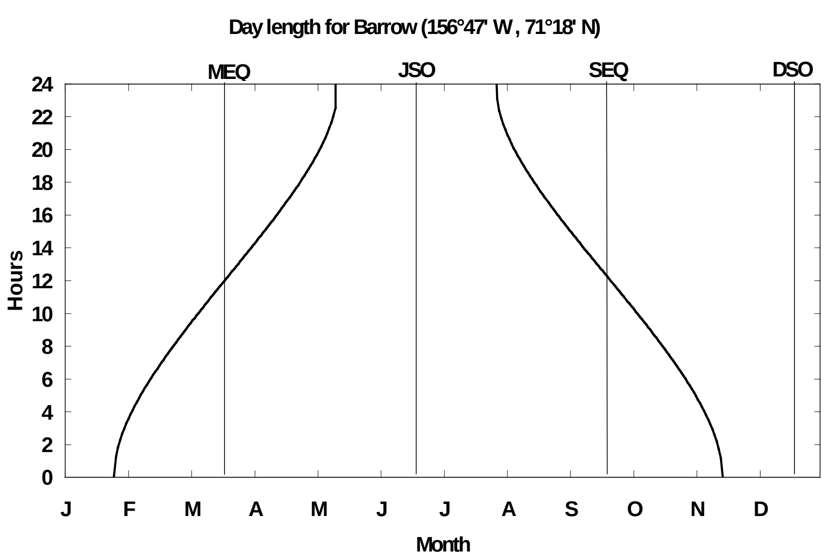

Figure 5.6.2.

Day length for Barrow. (MEQ = March equinox, JSO = June solstice, SEQ = September equinox, DSO = December solstice).

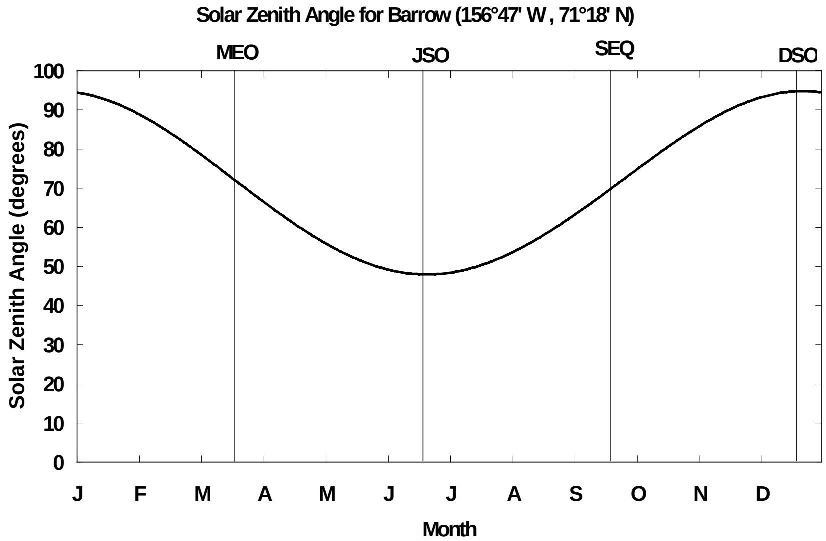

Figure 5.6 3. *Noontime solar zenith angle for Barrow.*

Figure 5.6.4. *The township of Barrow (left) and UIC-NARL (right) where the SUV-100 is housed. It is mounted toward the left side of the building roof. After snowmelt, with the Arctic Sea ice still extended to shore. Snow and ice coverage changes strongly impact the albedo, and can be seen in the irradiance data. At other times the sea is free of ice out to several hundred miles*

5.6.1. Weather Observations

Weather observations for Barrow, Alaska (WMO station number 70026) were obtained from the National Climatic Data Center (NCDC). The data are in a format described in Appendix A7 of this report. The file BARROW.CSV, can be found in the \WEATHER directory on the CD-ROM 7.0.b.

5.6.2. Ozone Observations

Table 5.6.1. TOMS ozone averages and minima for Barrow, February 1 – June 30.

	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	426.2	327	6/12/88												
1989	413.0	288	6/29/89												
1990	408.4	302	4/7/90												
1991	423.7	312	6/29/91												
1992	401.2	293	6/30/92	390.5	274	6/30/92									
1993				365.1	304	6/30/93									
1994				414.0	338	2/17/94							403.1	319	3/27/94, 3/28/94
1995													366.7	289	3/6/95
1996													384.9	286	3/2/96
1997							392.0	303	2/8/97, 6/26/97	388.2	292	6/24/97			
1998										432.8	342	6/9/98			

Note: 1994 TOVS data is only partially available; actual data starts month later on 3/1/96. TOMS/Earth Probe data is not available before February 11. The average was therefore calculated over a shorter period.

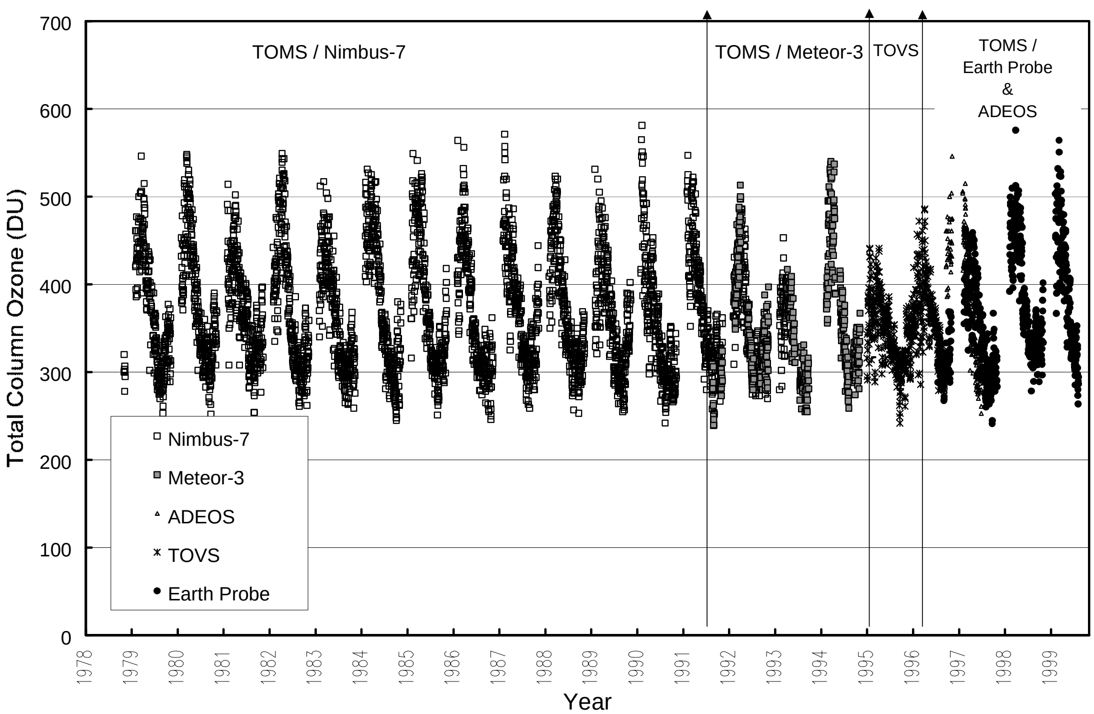

Figure 5.6.5. *Time record of total column ozone from TOMS and TOVS data.*

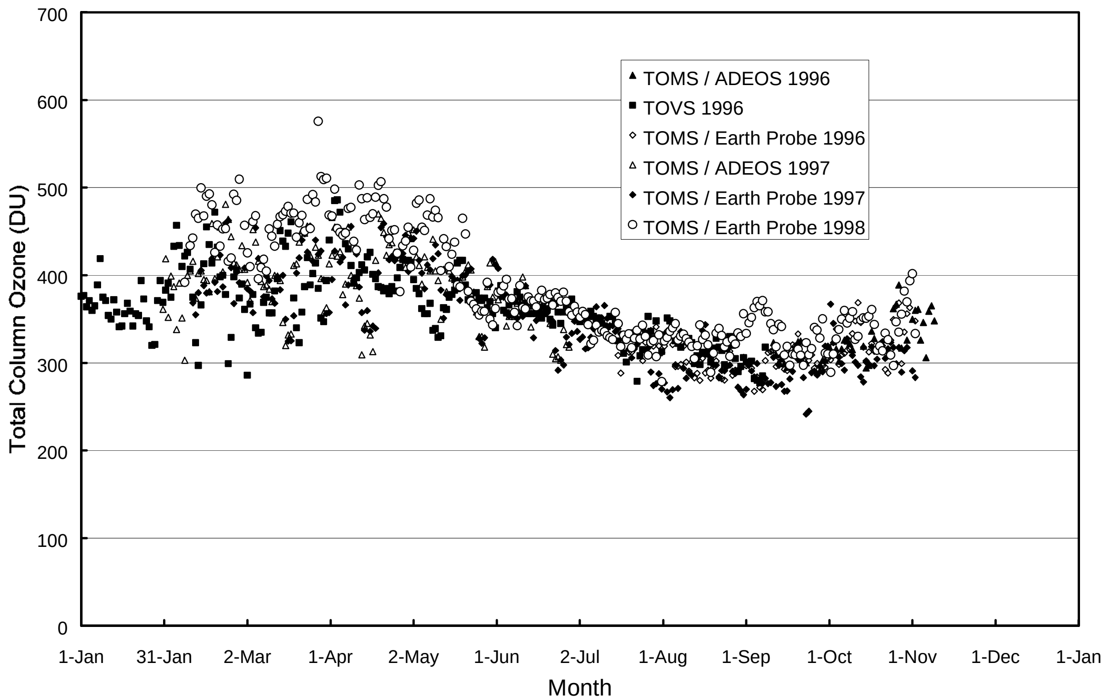

Figure 5.6.6. *Seasonal variation of ozone from TOMS and TOVS data at Barrow. The variability earlier in the year is much higher than later in the year. In contrast to the austral sites, minimum ozone values occur in fall. The differences between satellites are discussed in Appendix A6 "Ozone Data."*

5.6.3. Barrow 10/20/97-8/27/98

The 1997/98 season at Barrow is defined as the time between the site visits, 10/20/97 – 10/25/97 and 8/19/98 – 8/27/98. The season opening and closing calibrations were performed on 10/24/97 and 8/19/98, respectively. Solar data is available for the period 10/26/97 – 8/18/98. During this time, the system operated normally except for two periods when instrument and PMT temperature were out of range. This caused a reduced system responsivity, which was corrected, however, with the daily response scans. The impact on the accuracy of solar data was less than 2%.

5.6.3.1. Stability in the Wavelength Domain

As for the other sites, 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 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 5.6.7 shows the differences in the wavelength offset of the 296.73 nm Mercury line between two consecutive wavelength scans. In total, 305 scans have been evaluated. For 78% of the days, the change in offset is smaller than ±0.025 nm; for 98% of the days the shift is smaller than ±0.055 nm. Only 2 scans have an offset-difference that is larger than ±0.1 nm. These scans were taken between 5/25/98 and 6/9/98, when the monochromator temperature was out of range due to a problem in the temperature control circuit. The wavelength calibration of solar measurements may therefore be incorrect by up to 0.11 nm on the day affected.

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 5.6.8 shows the resulting correction function that was applied to the Volume 7 Barrow data. The wavelength-dependence of the function is caused by non-linearities if the monochromator drive. In order to demonstrate the difference between the result of the new Fraunhofer-correlation method and the method that was historically applied, Figure 5.6.8 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 0.083 nm. As explained in Section 3, the different light paths for internal wavelength scans and solar measurements cause this bias.

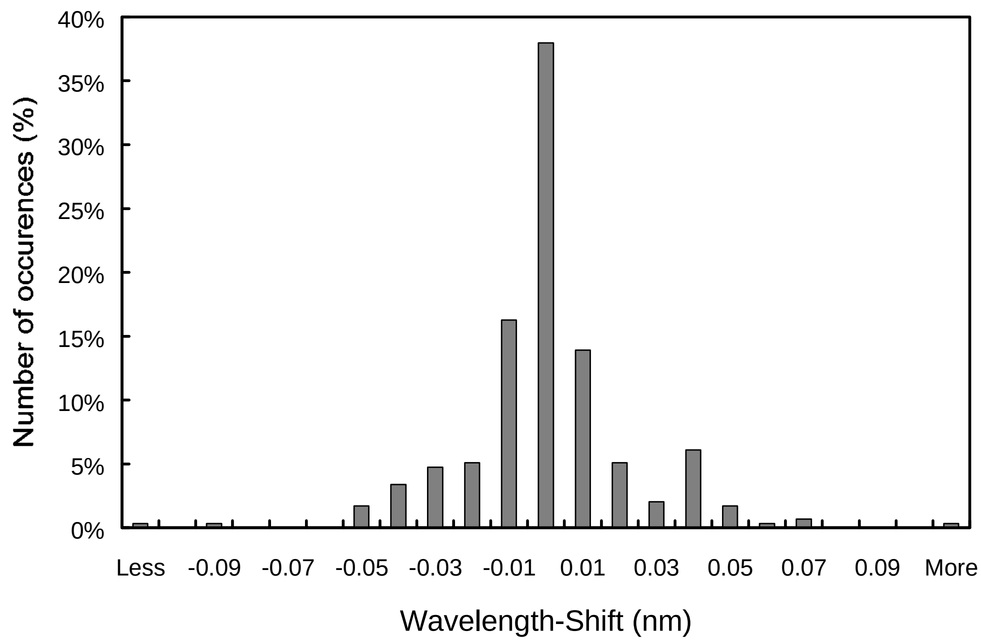

Figure 5.6.7. *Differences in the measured position of the 296.73 nm Mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. Thus the 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more" means shifts larger than 0.105 nm.*

After the data have been wavelength corrected using the shift-function described above, the wavelength accuracy was tested again with the Fraunhofer method. The result is shown in Figure 5.6.9. At 320 nm the wavelength shift for noontime measurements is smaller than ±0.05 nm throughout the season, with only a few exceptions. The slight drop in the plot at the end of May 1998 is caused by problems with the monochromator temperature stabilization mentioned above. 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 320 nm presented in Figure 5.6.9.

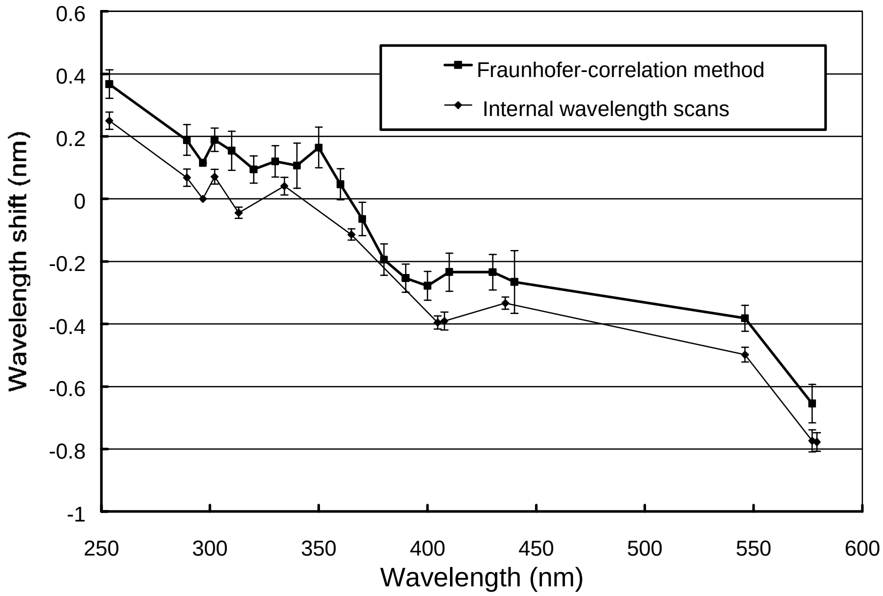

Figure 5.6.8. *Functions expressing the monochromator non-linearity for Barrow. Thick line: Function calculated with the Fraunhofer-correlation method. This function has been applied to correct the Barrow Volume 7 data. Thin line: Function calculated with the method that had been applied historically. The offset between both methods is 0.12 nm. Both functions represent average wavelength shifts for the 1997/98 season. The error bars give the 1σ standard deviation variation of the wavelength shifts.*

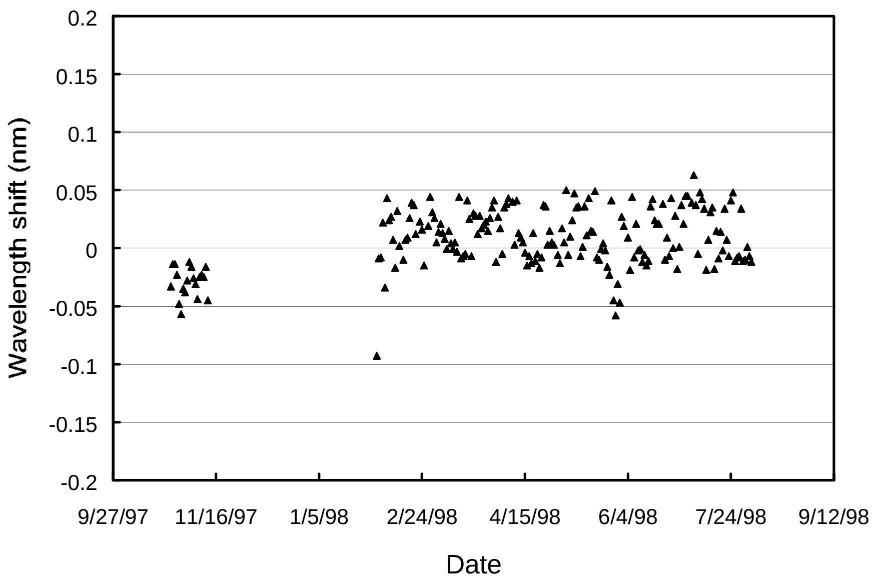

Figure 5.6.9. *Check of the wavelength accuracy of the final data at 320 nm by means of Fraunhofer correlation. For each day of the season the noontime measurement has been evaluated. The shift is smaller than ±0.05 nm for most days.*

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 5.6.10 illustrates the difference between internal and external Mercury scans collected during both site visits. External scans have a bandwidth of about 1.09 nm FWHM, whereas the bandwidth of the internal scan is only 0.80 nm. In addition, the peak of external scans is shifted towards longer wavelengths, compared to the internal peak. 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 5.6.10.

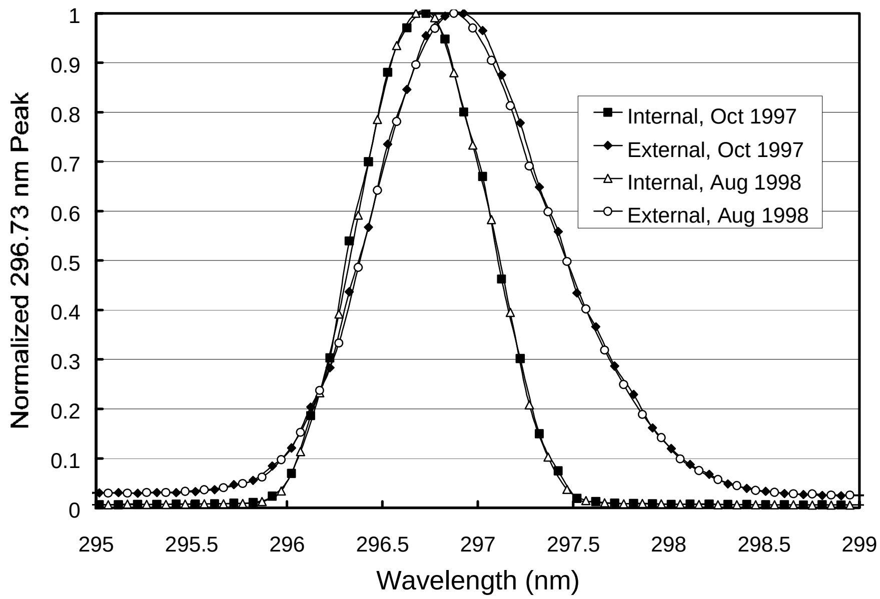

Figure 5.6.10. *The 296.73 Mercury spectral line as registered by the PMT from external and internal wavelength scans.*

5.6.3.2. Responsivity Stability

The stability of the response lamp and the responsivity of the Barrow spectroradiometer were primarily assessed with

- Total Scene Irradiance (TSI) measurements during response lamp scans, and
- Photomultiplier Tube (PMT) current at several wavelengths during response lamp scans.

Figure 5.6.11 shows the PMT current at 300 and 400 nm and the TSI behavior during the whole 1997/98 Barrow season. All data is normalized to the averages of the individual system parameters of the period. 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.

Figure 5.6.11 shows that the TSI response lamp measurements were stable to within ±1%. This is a strong indication that the response lamp drifted only slightly during the whole season. The PMT currents at 300 and 400 nm were stable to within ±3% over the season, with the exception of two periods. Due to a failure of the temperature control circuit, the monochromator temperature was high by up to 6 °C between 5/18/98 and 6/5/98 (line in Figure 5.6.11). This caused a decrease in the instrument's responsivity of up to 12%. Since the solar data are calibrated with the daily response scans this change in responsivity is automatically corrected. Between 6/23/98 and 7/18/98, the PMT cooler was defective causing a second period with reduced instrument responsivity.

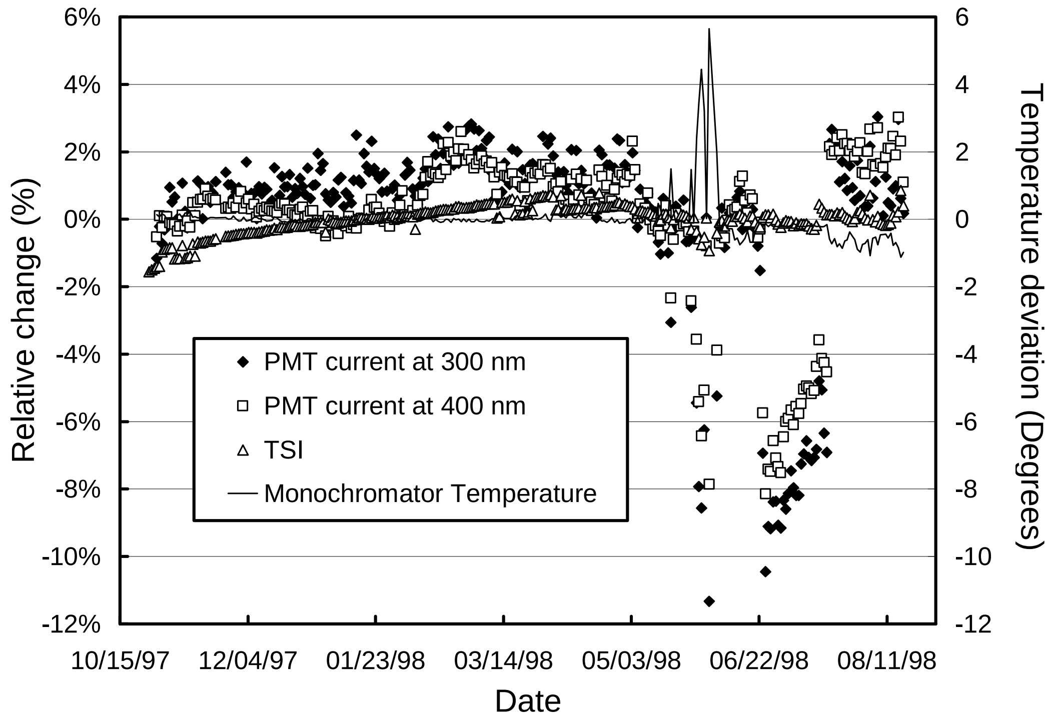

Figure 5.6.11. *Left axis: Time-series of PMT current at 300 and 400 nm and TSI signal during measurements of the response lamp in the whole McMurdo 1997/98 season. The data is normalized to the average of the whole season. Right axis: Deviation of monochromator temperature from desired value.*

Because of the extraordinary stability of the response lamp, the same mean-irradiance was assigned to the lamp throughout the whole Volume 7 season. From all 200-Watt calibrations with the lamps 200W009, M-699, M-762 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 5.6.12 shows the ratio standard deviation / average. Although calibrations during the whole season contributed to this plot, the standard deviation is only about 2% of the average for wavelengths above 350 nm. Towards the short-wave UV-B, the standard deviation increases, as can be expected.

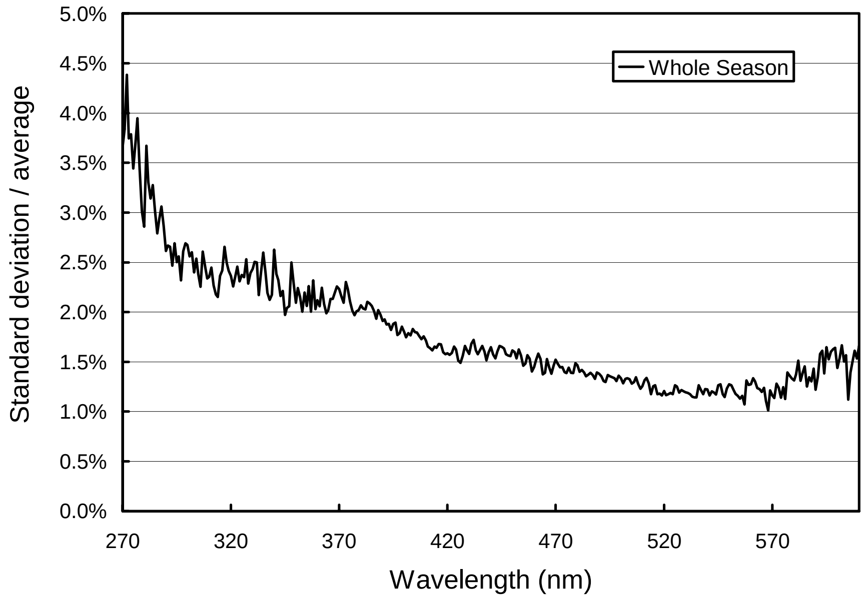

Figure 5.6.12. *Ratio of standard deviation and average calculated from all absolute calibration during the Volume 7 Barrow season.*

5.6.3.3. Lamp Intercomparison

The site standards for the Volume 7 Barrow season were the lamps M-699, M-762, and 200W009. As for the other sites, the traveling standard was M-874. All four lamps have been re-calibrated by Optronic Laboratories in September 1998, about one month after the season closing site visit. The 1998 Optronic Laboratories calibration values have been applied to all calibrations during the season.

Figure 5.6.13 shows the results of the season-closing calibrations. All lamps agree to within ±1%; the deviations are even smaller in the visible. This good agreement can be expected because of the Optronic Laboratories lamp calibration one month later. On the other hand, the lamps had to travel between the season closing activities and the re-calibration, which could have changed the calibration values. The good agreement therefore confirms that this series of Optronic Laboratories calibrations are consistent, that the lamps were insensitive to transportation (which is not always the case), and that an on-site calibration of lamps can be carried out without introducing large random and/or systematic errors.

Figure 5.6.14 shows the intercomparison of the same lamps but at the season opening. Lamp M-762, M-874 and 200W009 agree to within ±1.5%. The deviation is only slightly larger than for the season closing calibrations. The curve for M-699 (2 datasets included in the Figure) are about 2-3% lower than the cluster of the other three lamps. M-699 may therefore have drifted. The lamp was measured however one day before the other lamps after the systems had been dismantled and serviced. According to our experience it may take one to two days until the whole system is running stable again. Therefore season opening calibrations are usually under less ideal conditions than the season closing scans. The larger scatter in Figure 5.6.14 and the somewhat low readings of M-699 may be explained by this fact.

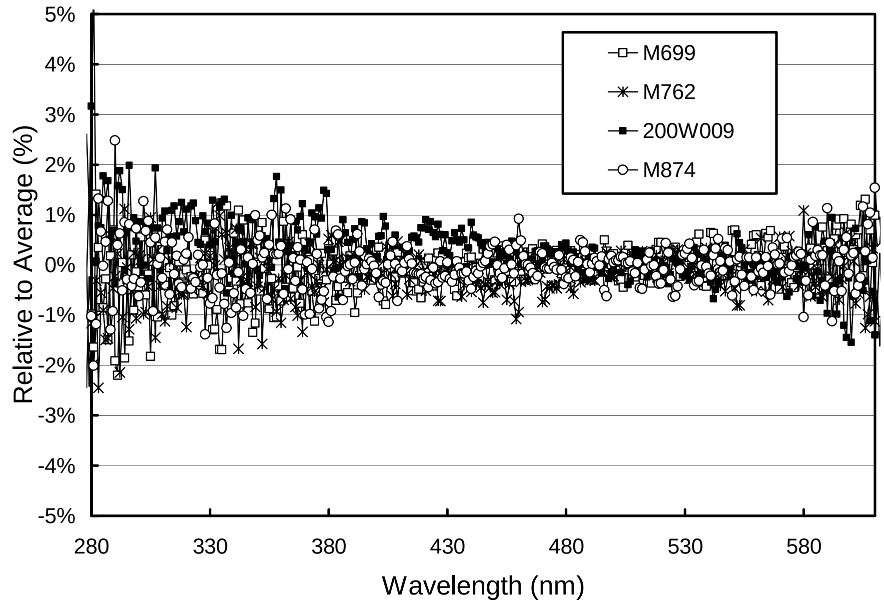

Figure 5.6.13. *Result of season closing calibrations at Barrow, 8/19/98: Comparison of Barrow lamps M-699, M-762, 200W009, and the traveling standard M-874.*

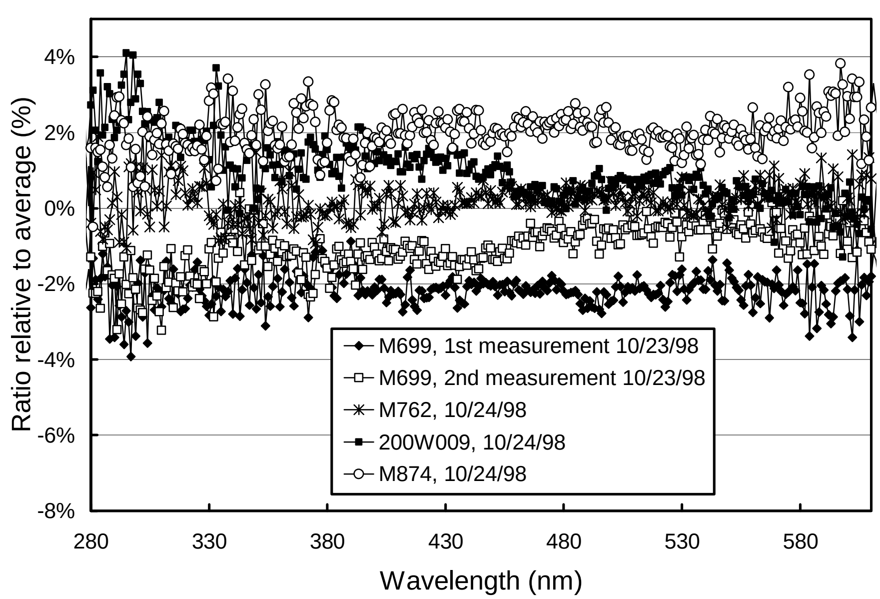

Figure 5.6.14. *Result of season opening calibrations at Barrow. Lamp M-699 was measured one day before the other lamps.*

5.6.3.4. Missing Data

A total of 15224 scans with an SZA smaller than 92° were scheduled to be measured in the Barrow Volume 7 season. In winter (10/26/97-2/2/98) only one scan per hour was measured and no scans between 11/27/97 and 1/13/98 are included in Volume 7 because of the Polar Night. From 2/3/98 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, when scans were only taken every 30 minutes. A total of 14628 scans, 96.1% from the scans scheduled, were actually measured, and 13531 scans (88.9%) were included in Volume 7. The discrepancy of 596 scans between scheduled and measured data scans is primarily caused by other scan types, which superseded solar measurements. Since Barrow has 24 hours of sunlight per day in summer, a loss of some data scans cannot be avoided. For example, 184 data scans were lost because they were superseded by response scans. Similarly, wavelength scans lead to the loss of 94 data scans. Data scans on 6/3/98 and 6/4/98 (170) were lost because of the failure in the instrument's temperature stabilization. Finally, approximately 140 data scans were superseded by absolute calibrations performed during the day.

1097 of all data scans measured were found to be defective and were therefore not included in Volume 7. Fifty five of these scans were from day 3/29/98 and were excluded because of an incorrect time assignment.