5.6. Barrow, Alaska (01/13/01 – 10/18/01)

The 2001 season at Barrow is defined as the time between the site visits 12/11/00 – 12/19/00 and 10/18/01– 10/24/01. The season opening and closing calibrations were performed on 12/18/00 and 10/18/01-10/19/01, respectively. Volume 10 solar data comprise the period 01/13/01 – 10/18/01; the first day marks the end of the polar night defined as the time when the solar zenith angle during solar noon is smaller than 95°. During the site visit in 2000, a new computer was installed. The new system hung several times in the weeks following the service due to a problem with one of its device drivers. The problem disappeared after reinstalling the drivers on 2/24/01. Several days of data were lost prior to this day due to the software conflict.

The system was affected by a gradual decrease in responsivity; at the end of season, the instrument was approximately 25% less sensitivity than at the beginning. The inspection of the system during the site visit in October 2001 revealed that dust from wear of the shutter collected on the relay lens below the shutter and on the window above the shutter leading to attenuation of incoming radiation. All other system components (monochromator, optics block, internal irradiance standard, PMT) were stable at the ±1.5% level. These changes in responsivity due to the accumulation of the abrasion of the shutter were compensated for by appropriately adjusting the calibration files. In certain periods, however, the calibration uncertainty is larger than usual (see Table 5.6.1).

The collector of the instrument was modified during the site visit in December 2000. This upgrade, which was implemented at all sites during 2000, resulted in substantially decreased azimuth errors, which affected solar data of previous volumes (see the introduction to Chapter 5). In addition, the relay lens of the optics block (see Figure 2.1 of Chapter 2) was replaced with a lens of larger focal length, leading to a higher system sensitivity. This gain in sensitivity compensated for the reduction in sensitivity due to the collector upgrade. Data analysis did not indicate a significant step-change in time-series of noon-time solar irradiance measurements or daily dose data introduced by the upgrade. However, small systematic changes at low solar elevations cannot be excluded. An investigation on the effect of the cosine error on network data is in preparation.

Due to problems in reading the GPS receiver drifts of the computer time were not automatically corrected on a daily bases as usual. The computer clock was reset on 7/4/01, 7/10/01, 7/16/01, and 8/14/01. At these days, the clock was slow by 54, 15, 17, and 78 seconds respectively. Published data were not corrected for these time errors.

About 92.5% of the scheduled data scans are part of the published dataset; 4% of all scans were lost because of technical problems.

During the site visit in December 2000, the PSP and TUVR instruments were removed, returned to Eppley Laboratories for recalibration, and installed again on 3/9/01. The new calibration factors, established by Eppley on 12/28/01 and 12/29/00 were applied to all data of the Volume 10 season. Note that PSP and TUVR are not heated or ventilated. Since the instruments are only cleaned once per week snow may accumulate leading to a reduction in signal. In particular data from the first half of 2001 are affected.

5.6.1. Irradiance Calibration

The site irradiance standards for the 2001 Barrow season were the lamps 200W009, M-762, and M-699. The lamp M-764 was used as the traveling standard. All three site standards and the traveling standard were re-calibrated by Optronics Laboratories in March 2001. This calibration was applied throughout the season.

Figure 5.6.1 shows a comparison of all lamps at the beginning of the season (12/18/00). Lamps 200W009 and M-764 agree to within ±0.5%. The calibrations of lamps M-762, and M-699 deviate by 1-2% from those of 200W009 and M-764. This difference is still within the uncertainties of the calibration standards. Figure 5.6.2 shows a similar comparison of all lamps for the end of the season. All lamps agree to within ±1%.

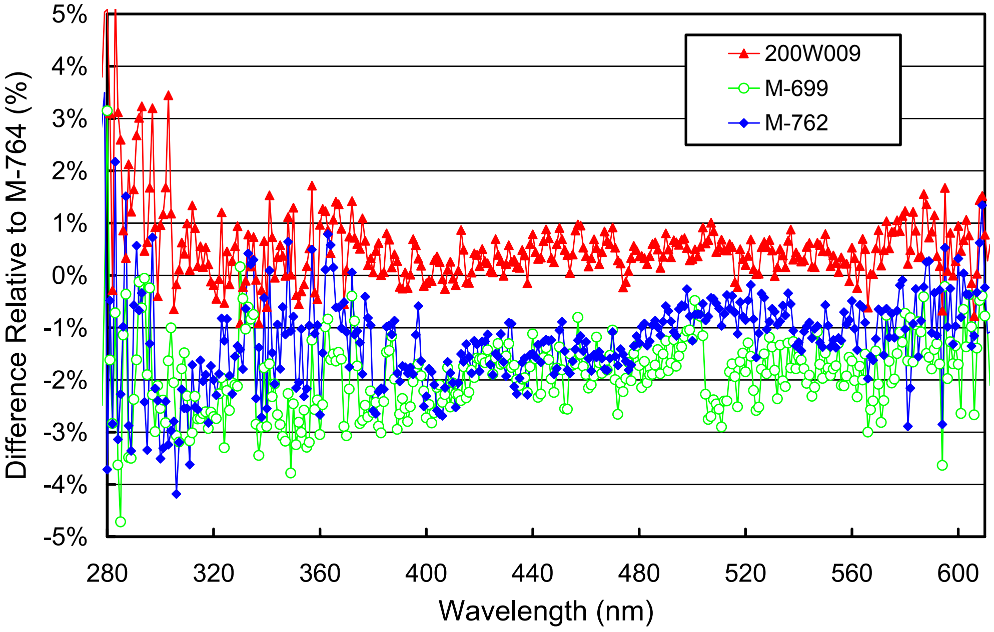

Figure 5.6.1. *Comparison of Barrow lamps 200W009, M-762, and M-699 with the BSI traveling standard M-764 at the beginning of the season.*

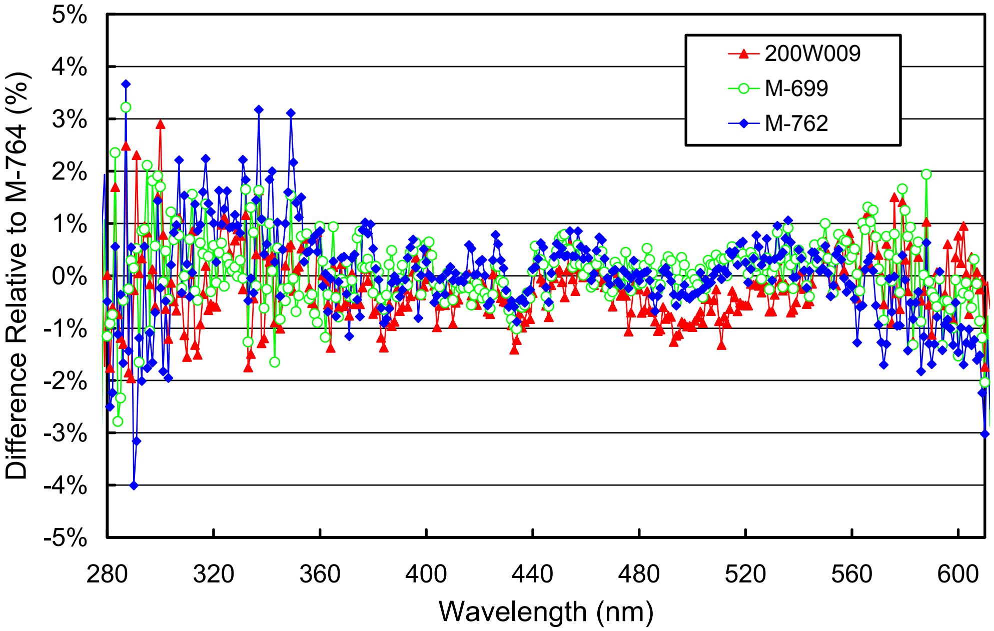

Figure 5.6.2. *Comparison of Barrow lamps 200W009, M-762, and M-699 with the BSI traveling standard M-764 at the end of the season.*

5.6.2. 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. The stability of the internal lamp is monitored with the TSI sensor, which is independent from possible monochromator and PMT drifts. Usually a new irradiance is assigned to the internal lamp when TSI measurements indicate that the lamp has drifted by more than 2%. This procedure could not be applied to Barrow Volume 10 data since the internal lamp was stable to within ±1.0% during the whole season, although absolute calibrations showed a drift of 25% during the same period. This drift was due to dust from the shutter accumulating on the instrument's relay lens. This part of the system is not monitored with the internal lamp scans.

Figure 5.6.3 shows the changes in TSI readings and PMT currents at 300 and 400 nm, derived from the daily response scans. The TSI measurements indicate that the internal lamp was stable to within ±1%. Changes in the PMT currents during scans of the internal lamp were less than ±2%.

The drift caused by the shutter dust was analyzed and corrected based on the bi-weekly calibrations with the 200-Watt standards. This analysis suggested that 10 different irradiance spectra have to be assigned to the internal lamp to keep uncertainties caused by the drifts below the target value of ±2.0%. When changes between two consecutive calibrations were larger than 2%, the affected period was split in two or more parts. In each part, interpolated values were applied, which were calculated from the encompassing absolute scans. This is possible since the observed drift is a smooth function of time. The dashed lines in Figure 5.6.3 indicate the dates when a new calibration file was applied. Note that the system was quite stable after 7/10/01 until the end of the season (Period 9).

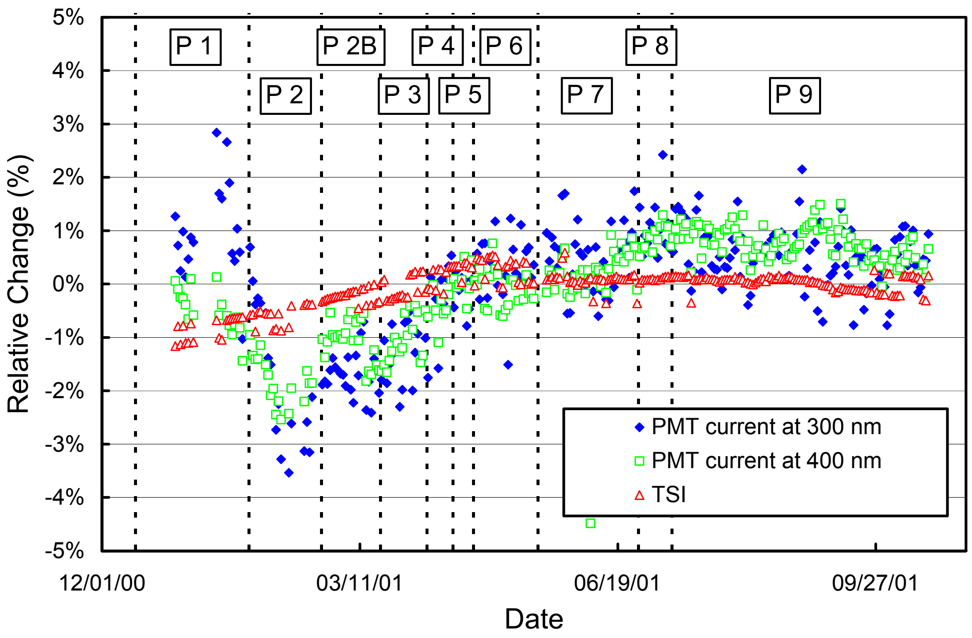

Figure 5.6.3. *Time-series of PMT current at 300 and 400 nm, and TSI signal, during measurements of the internal irradiance standard during the Barrow 2000-2001 season. All data sets are normalized to the average. Vertical dashed lines indicate dates when the calibration of the system was changed.*

Figure 5.6.4 shows the ratio of the irradiance assigned to the internal lamp in all 10 periods, referenced to Period 1. In order to find the reason of the observed drifts, the collector of the system was removed on

5/18/01, between Period 6 and Period 7. The calibration series was consequently broken on 5/18/01. The calibrations applied during Period 6 and 7 differ by approximately 5-6%. Although there were no absolute calibrations performed between 5/7/01 (last absolute scan of Period 6) and 6/2/01 (first scan of Period 7), it is very likely that the instrument's responsivity actually changed by 5-6% on 5/18/01. The alternative hypothesis of a gradual change in responsivity between 5/7/01 and 6/2/01 is small. The occurrence of an abrupt change can be concluded from the fact that the ratio of TSI measurement performed during solar scans and spectral measurements weighted with the response function of the TSI is constant both during Period 6 and Period 7. This example shows the usefulness of the TSI to check the system's stability over time in the absence of absolute calibrations. In can therefore be concluded that the uncertainty in solar measurements is not increased during the 5/7/01 - 6/2/01 period.

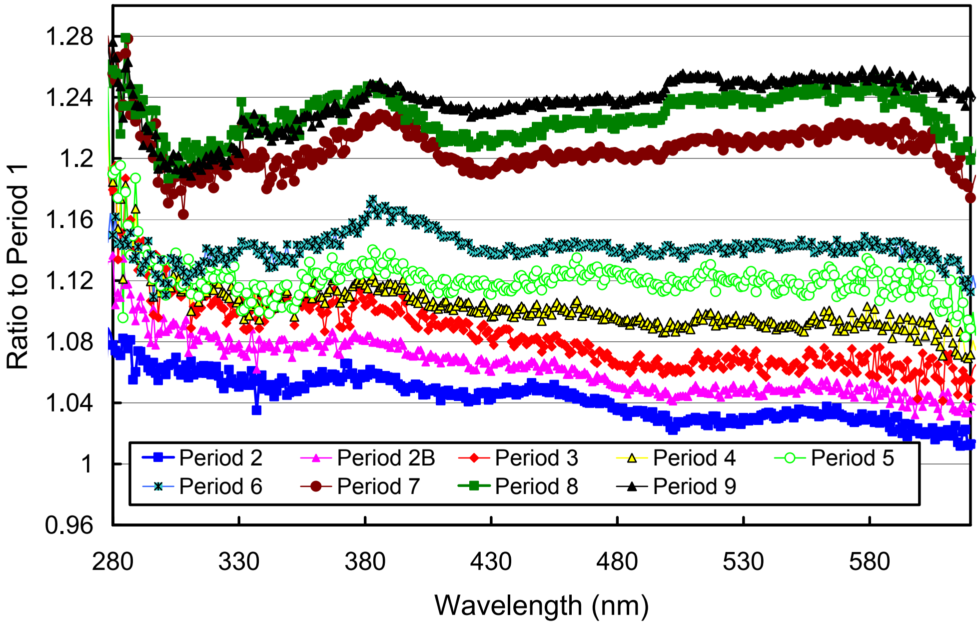

Figure 5.6.4. *Ratios of irradiance assigned to the internal reference lamp, referenced to Period 1.*

Table 5.6.1 gives for each period the 1-σ calibration uncertainty that is caused by the instrument drift. Note that this uncertainty is only a measure of the variability of calibrations in a given period. It is not the total calibration uncertainty, which would also include uncertainties in the calibration values of standard lamps. In periods when the system was stable the calibration file was derived by averaging the results of all absolute scans performed in this period (see Section 4.2.1.2 for details). These periods include periods P1, P2, P6, P7, P8, and P9. The uncertainty for each of these periods is the ratio of standard deviation and average irradiance calculated from all calibration files performed in that period. These ratios are plotted in Figure 5.6.5. The 1-σ uncertainty is typically ±1.5% in the UV-B and ±1% in the visible. The uncertainty for periods when the calibration file was derived by interpolation was calculated from the uncertainty of the two calibration functions that formed the starting-point of the interpolation, and the difference of those functions. The highest 1-σ uncertainty was found to be 2.9%. In spite of the observed drifts, uncertainties in published solar data therefore remain within reasonable limits.

Table 5.6.1. 1-σ standard uncertainty of system calibration caused by responsivity drifts.

Period			Number of absolute scans	Standard uncertainty in %			Remarks
Label	Start	End		UV-B	UV-A	VIS	
P1	12/14/00	1/26/01	8	1.6	1.2	1.0	Standard calibration
P2	1/27/01	2/23/01	4	2.6	1.4	1.0	Standard calibration
P2B	2/24/01	3/18/01	0	2.9	1.9	1.4	Interpolation
P3	3/19/01	4/5/01	1	1.5	1.3	1.4	Single scan
P4	4/6/01	4/15/01	0	1.3	1.1	1.5	Interpolation
P5	4/16/01	4/23/01	1	1.3	1.4	1.5	Single scan
P6	4/24/01	5/19/01	4	1.2	1.0	0.8	Standard calibration
P7	5/20/01	6/26/01	3	1.0	0.8	0.5	Standard calibration
P8	6/27/01	7/9/01	3	1.2	0.8	0.7	Standard calibration
P9	7/10/01	10/21/01	15	1.4	1.0	0.6	Standard calibration

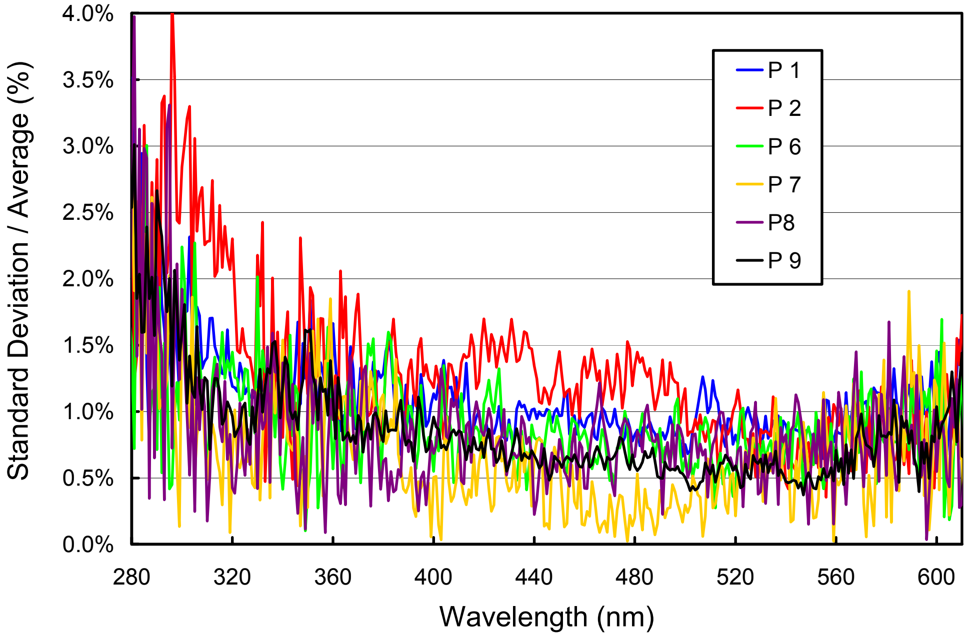

Figure 5.6.5 *Ratio of standard deviation and average calculated from the absolute calibration scans of selected periods.*

5.6.3. 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 5.6.6 shows the differences in the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 393 scans were evaluated. For 77% (95%) of the days, the change in offset was smaller than ±0.025 nm (±0.055 nm). Only two scans showed a change larger than ±0.1 nm related to system service. The data was corrected accordingly.

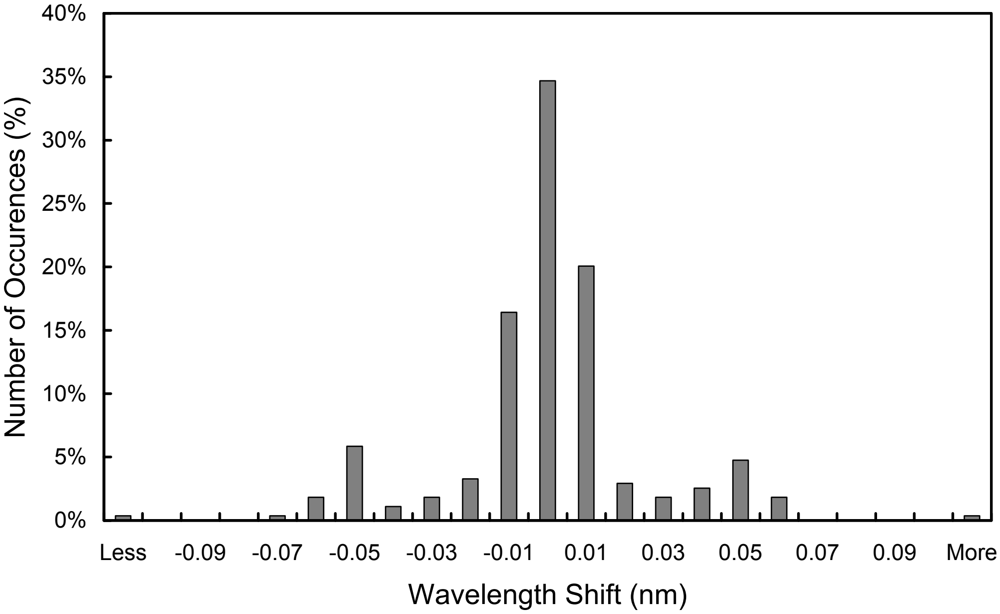

Figure 5.6.6. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. Thus the 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more" 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 4. The thick line in Figure 5.6.7 shows the resulting correction function that was applied to the Volume 10 Barrow data. The function depends upon wavelength, which is caused by non-linearities of the monochromator drive. In order to demonstrate the difference between the result of the Fraunhofer-correlation method and the method that was historically applied, Figure 5.6.7 also includes the 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 approximately 0.05 nm. As explained in Section 4, this bias is caused by the different light paths for internal wavelength scans and solar measurements. The bias is smaller compared to the differences reported in previous volumes. This can be explained by the change in the optical path introduced by the collector modification performed during the site visit in December 2000.

After the data was wavelength corrected using the shift function described above, the wavelength accuracy was confirmed again with the Fraunhofer method. The results are shown in Figure 5.6.8 for four UV wavelengths, evaluated for all noontime scans measured during the season. The residual shifts are ±0.03 nm (±1σ), except of some outliers that are likely caused by cloud effects. The actual wavelength uncertainty may be larger due to wavelength fluctuations of about ±0.02 nm during the day, and possible systematic errors of the Fraunhofer-correlation method (see Section 4).

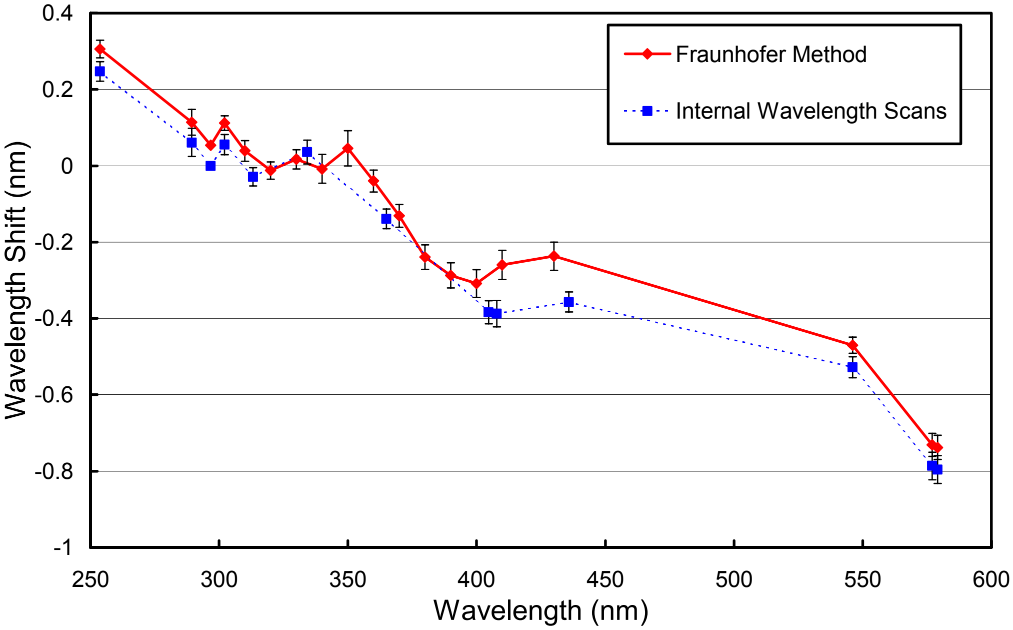

Figure 5.6.7. *Monochromator non-linearity for the Barrow 2000-2001 season. Solid line: correction function calculated with the Fraunhofer-correlation method, applied to correct the Barrow Volume 10 data. Thin broken line: correction function calculated with the method that was historically applied. The mean offset difference between both methods is 0.05 nm. The error bars show the 1σ standard deviation of the wavelength shifts for the season.*

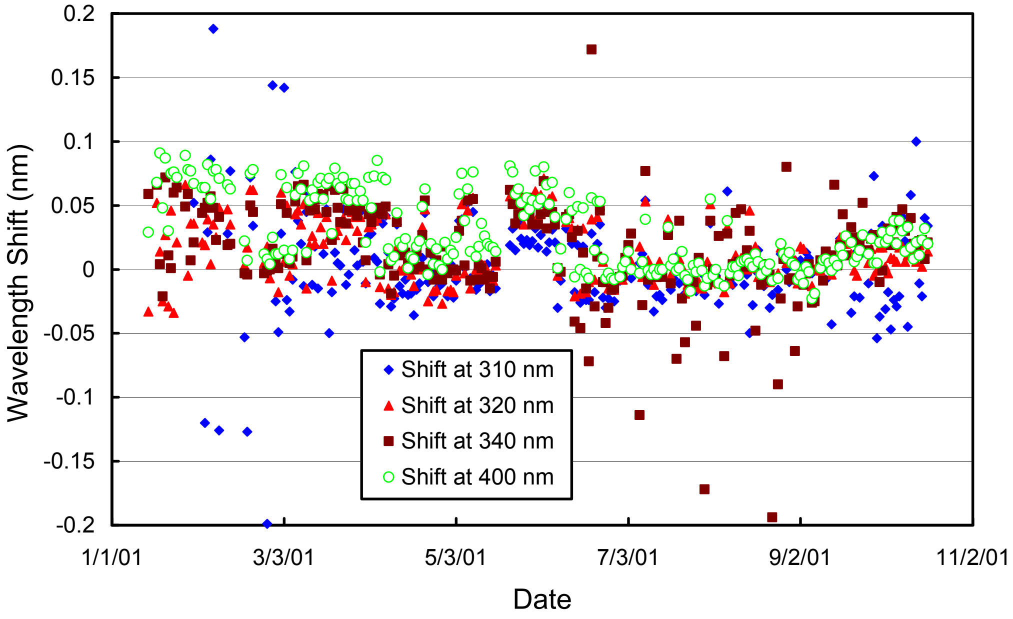

Figure 5.6.8. *Wavelength accuracy check of the final data at four wavelengths by means of Fraunhofer correlation. The noontime measurement has been evaluated for each day of the season when the sun was above the horizon.*

Although 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 5.6.9 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. External scans have a bandwidth of about 0.98 nm FWHM, whereas the bandwidth of the internal scan was about 0.76 nm. Figure 5.6.9 indicates that the season opening (December 2000) and season closing (October 2001) scans appear to be shifted by approximately 0.04. This is within the range of residual wavelength shifts after wavelength correction (see also Figure 5.6.8). The center wavelengths of internal and external scans agrees to within 0.04 nm. This is a better agreement than in previous seasons and may be attributable to the diffuser upgrade in 2000, which also changed the optical paths of the two scan types. External scans better represent the monochromator bandpass relevant for solar scans as they have the same light path.

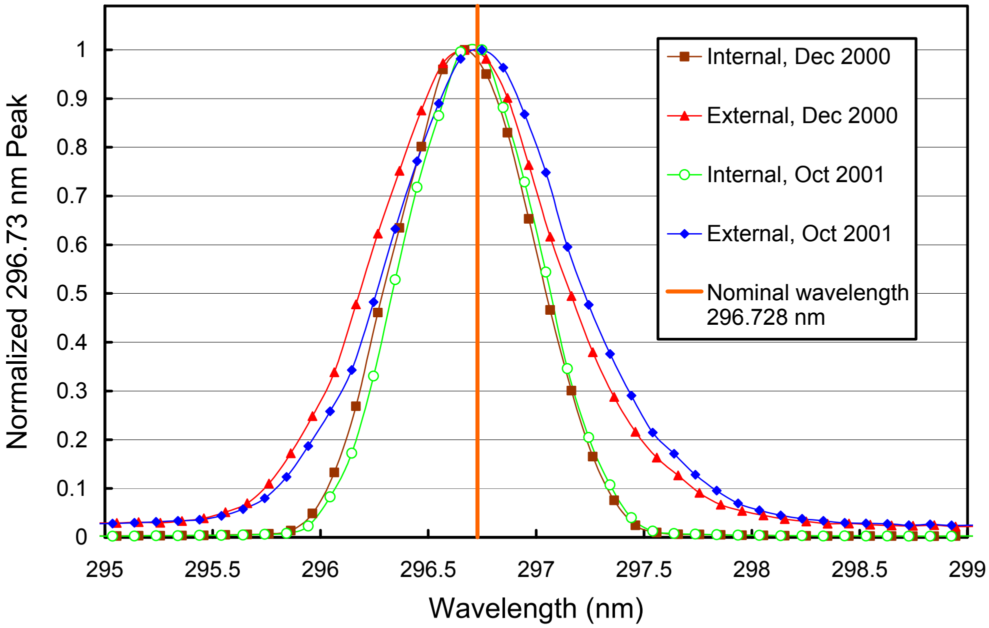

Figure 5.6.9. *The 296.73 mercury line as registered by the PMT from external and internal sources at the start and end of the season. The wavelength scale is the same as applied for solar measurements, i.e., it is based on a combination of internal scans and the Fraunhofer-correlation method. It is assumed that the wavelength registration of the monochromator did not shift between internal and external scans, which were close in time.*

5.6.4. Missing Data

A total of 17371 scans are part of the published Barrow Volume 10 dataset. These are 92.5% of all scans scheduled. About 4% of the scans were missed due to technical problems. Of all missing scans, 156, 194, and 287 were superseded by absolute, wavelength, and response scans, respectively. Due to a conflict with a device driver after installation of a new computer during the site visit in 2000 a total of 352 scans were lost. Following periods are affected: 1/16/01 (11 scans), 1/25/01-1/27/01 (38 scans), 1/31/01-2/1/01 (30 scans), 2/9/01-2/10/01 (45 scans), 2/13/01-2/16/01 (116 scans), and 2/21/01-2/24/01 (112 scans). After re-installation of the drivers on 2/24/01 the problem disappeared. Due to a full hard drive cartridge, 392 scans were lost between 5/18/01 – 5/22/01. Data quality control revealed that 12 scans from days 6/7/01 and 6/8/01 had a calibration problem and were therefore disregarded. In addition, the time stamp of 13 scans measured on 4/1/01 was incorrect and the affected scans were excluded from the published dataset.