5.4. Ushuaia, Argentina (4/20/98– 8/24/99)

The 1998-99 season at Ushuaia is defined as the time between the site visits 4/10/98 – 4/19/98 and 8/26/99 – 9/2/99. The season opening and closing calibrations were performed on 4/16/98 and 8/24/99 – 8/26/99, respectively. Volume 8 solar data comprises the period 4/20/98 – 8/25/99. Measurements during this period were affected by several system problems. The quality of published solar data is only marginally compromised because all system malfunctions could be corrected during data processing:

- The through-the-collector throughput of the instrument decreased by 10-15% over the season, depending on wavelength. This is because dust from wear of the shutter—which is located immediately above the relay lens—collected on the lens, decreasing its transmission. The changing responsivity of the system was corrected by adjusting irradiance values of the internal reference lamp accordingly.

- The daily measurements of the internal irradiance reference were unstable during 5/11/98 and 6/30/98. The problem was caused by a loose contact at one of the lamp's terminals. Response scans during the affected period were discarded and therefore could not be used to track the stability of the instrument on a daily basis. All other system parameters indicated that the instrument itself was stable and only slightly affected by the gradual and predictable decrease of the throughput due to the shutter dust. The additional uncertainty in solar measurements in this period is estimated to be ±1.5%.

- There were power failures during at least 25 days of the season. Although the system is equipped with an uninterruptible power supply (UPS), most of the power outages were not buffered. The duration of some power outages were too long for the UPS battery capacity and in addition, the system batteries were at end-of-life. They were replaced on 8/20/99, shortly before the start of the 1999 site visit. Because of these power outages, the wavelength position of the monochromator was often lost, which is also indicated by the difference in the offsets calculated from consecutive wavelength scans. Before and after the occurrence of a wavelength change, the offset was very stable. By appropriately adjusting the paring of wavelength and data scans, the problem could be corrected and the wavelength accuracy of the published data is therefore not significantly impacted. Because of the power problem and the resultant wavelength stability problem about 280 data scans were lost or had to be discarded. In spite of this, almost 97% of scheduled data scans were found to be of good quality and are therefore part of the published dataset.

5.4.1. Irradiance Calibration

The irradiance standards for the 1998-99 Ushuaia season were the lamps 200W008, M-698, and M-766. As with all other sites, lamp M-874 was the traveling standard, which was used during season opening and closing calibrations. The lamp has two calibrations from Optronic Laboratories, one from August 1995 and one from September 1998. As mentioned in the introduction to Section 5, there are strong indications that the lamp has drifted by 2% between the beginning and middle of 1998. For the closing calibrations in 1999, the Optronic Laboratories calibration from 1998 was used, because M-874 appears to have been very stable from the second calibration date onward. The calibration of M-874 in April 1998 (the time of the site visit at Ushuaia) is somewhat doubtful and therefore comparisons of other lamps with M-874 performed during this time have to be treated with caution.

Lamp 200W008 was first used during the 1997-98 season and has an irradiance calibration of Optronic Laboratories from November 1996. Lamp M-698 does not have a calibration from an independent standards laboratory. For use in the 1998-99 season, a calibration was transferred to the lamp by comparing several absolute scans from M-698 and M-874, which were centered around the 1999 site visit. For M-874, the Optronic Laboratories calibration values from 1998 have been used. The method of the transfer is described in detail in Section 4.2.1.5.

Lamp M-766 has an Optronic Laboratories calibration from October 1992. Since the calibration of the lamp appears to have drifted since this time, a new calibration was established for use in the Ushuaia 1997-98 season. The calibration was transferred from M-874 in the same way as for M-698. For M-874, the Optronic Laboratories calibration values from 1998 have been used, and absolute scans applied from days 8/24/99 and 8/26/99.

Figure 5.4.1 shows a comparison of all lamps at the end of the season (8/24/99 and 8/26/99). All lamps agree to within ±1%. The good agreement of lamps M-698 and M-766 with M-874 can be expected as both lamps were calibrated with M-874 at approximately the same time. The validity of the calibration of M-874 is confirmed by the good agreement with lamp 200W008, which has an independent calibration.

The site standards 200W008, M-698, and M-766 were measured several times back-to-back during the season. The pattern is very similar for all days; lamps M-698, and M-766 agree to within ±0.5% and deviate by approximately 1-1.5% from 200W008. Figure 5.4.2 gives an example of the lamp comparison on day 7/2/98.

Figure 5.4.3 shows a comparison of all site standards with M-874 at the beginning of the season. The ratios for all lamps are lower than one in the UV, with deviations reaching 3-4% at 300 nm. In the visible, the ratios are higher than one. This pattern is the same for all lamps, suggesting that the reasons for the differences lies in the common reference, lamp M-874. As mentioned above, the calibration of the traveling standard is not reliable during this time of the year, which explains the observed discrepancies. Note that the ratios in Figure 5.4.3 would move further down if the Optronic Laboratories calibration from 1998 rather than the one from 1995 had been used for M-874 on day 4/16/98. Solar data are only slightly affected by the drift of M-874 since all site standards, including the independent lamp 200W008, agree on the 1.5% level throughout the 1998-99 season.

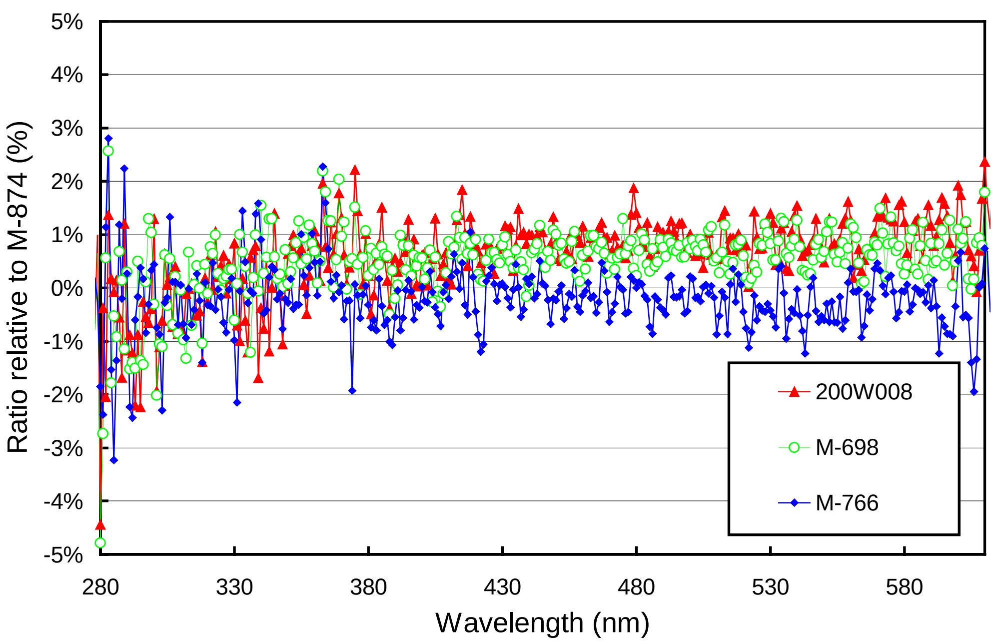

Figure 5.4.1. *Comparison of Ushuaia lamps 200W008, M-698, and M-766 with the BSI traveling standard M-874 at the end of the season (days 8/24/99 and 8/26/99).*

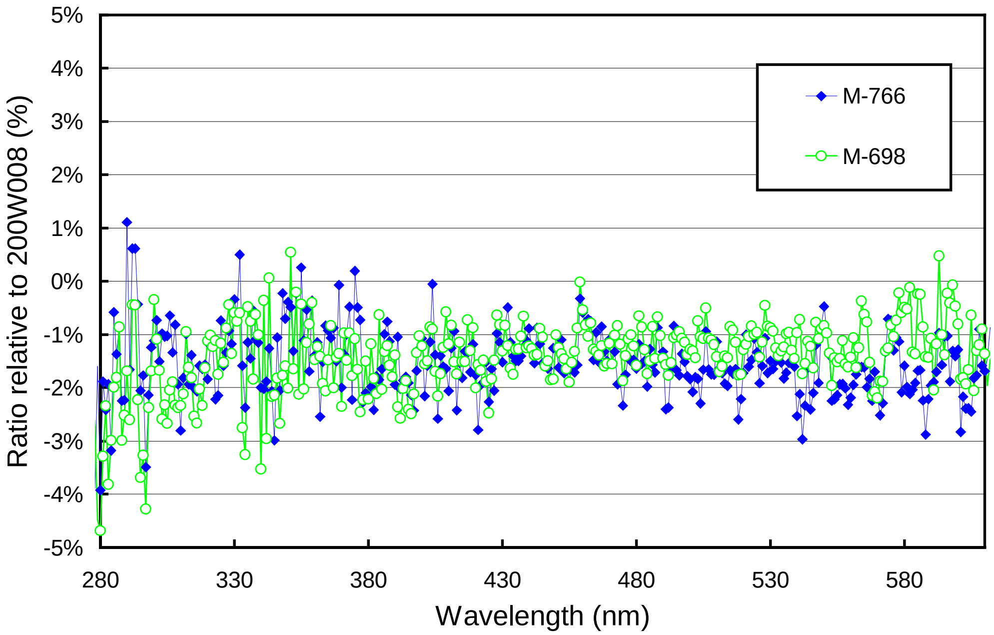

Figure 5.4.2. *Comparison of Ushuaia lamps M-698 and M-766 with 200W008 on 7/2/98.*

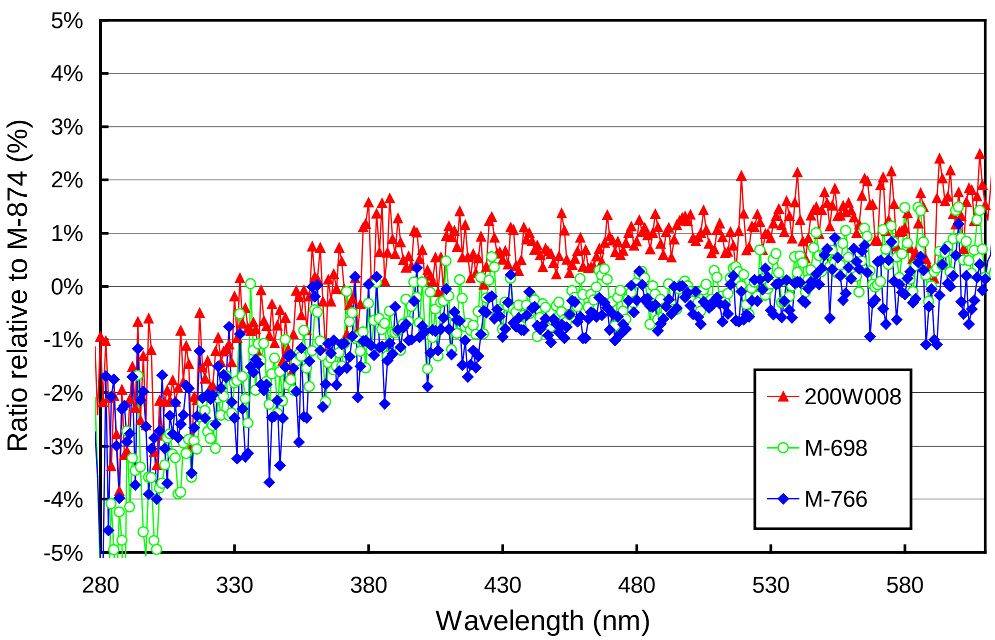

Figure 5.4.3. *Comparison of Ushuaia lamps 200W008, M-698, and M-766 with the BSI traveling standard M-874 at the beginning of the season (4/16/98).*

5.4.2. Instrument Stability

The stability of the spectroradiometer over time is primarily monitored with bi-weekly calibrations utilizing 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. When TSI measurements indicate that the internal lamp has drifted by more than 2%, a new irradiance is assigned to this lamp, based on the bi-weekly absolute calibrations (see Section 4.2.1.2).

By logging the PMT currents at several wavelengths during response scans, changes in the instrument responsivity can be detected. Note that this check is only suitable to discover changes in the light path between the internal reference lamp and the PMT. Changes in the upper part of the collector and the optics block, including the relay lens, cannot be unambiguously detected. The reduction of the transmission of the lens due to dust from shutter (see introduction of Section 5.4.) went therefore undetected by response lamp scans. In order to quantify these changes, time-series of PMT-currents, measured at specific wavelengths during scans with the site standards, were evaluated. Combining the results from measurements of internal and external light sources, drifts of the monochromator/PMT section of the instruments could be separated from the dust deposits.

Figure 5.4.4 shows the changes in TSI readings and PMT currents at 300 and 400 nm, derived from the daily response scans of the Ushuaia 1998-99 season. Period 1 (4/15/98-6/30/98) is affected by the loose connection of one of the terminals of the internal irradiance reference; therefore all quantities indicate a high scatter. As previously stated, response scans of this period could not be used. After this problem was solved on 6/30/98, the change of all parameters was very smooth. The TSI-sensor measurements indicate that the internal lamp was very stable in Period 2 (7/1/98-12/10/98). During Periods 3 (12/11/98-5/31/99) and 4 (6/1/99-8/28/99), the lamp became less intense by about 3.5% in the UV. The darkening of the lamp is well tracked with the readings of the PMT currents at 300 and 400 nm, suggesting that the monochromator and PMT were very stable in Periods 2 and 3.

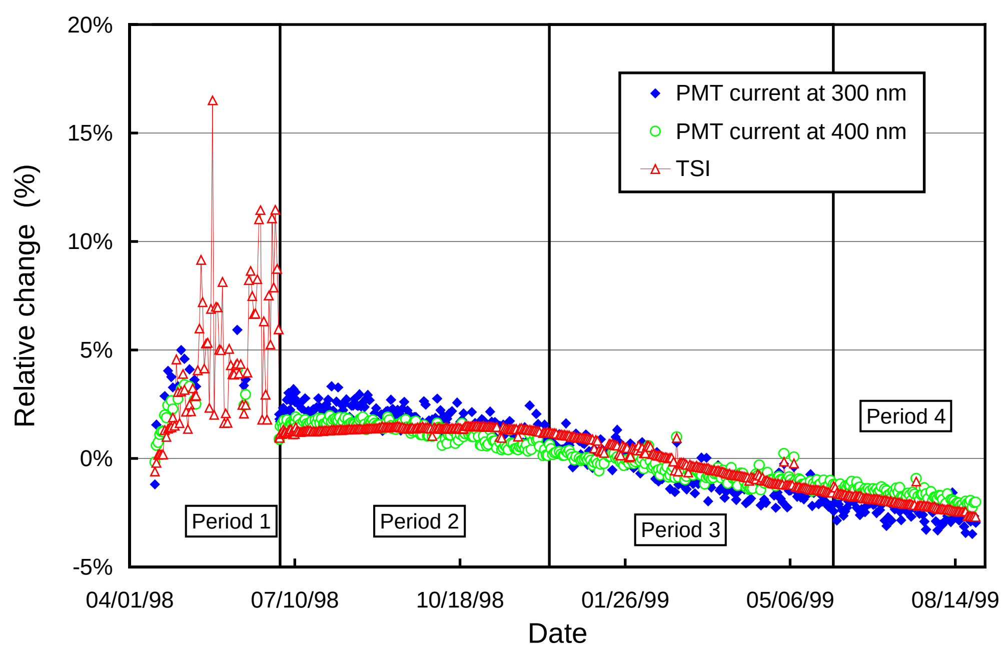

Figure 5.4.4. *Time-series of PMT current at 300 and 400 nm and TSI signal during measurements of the response lamp during the Ushuaia 1998-99 season. The data is normalized to the average of Periods 2-4.*

Figure 5.4.5 shows the change of the PMT current at several wavelengths during measurements of the site standard 200W008 through the collector. There is an almost linear drift over the season. The PMT current at 300 nm is approximately 14% higher at the beginning of the season than at the end. The PMT currents at 500 and 600 nm drift by about 12% and 9%, respectively. These drifts are believed to be due to dust on the relay lens, and are larger than the PMT current drift of about 5%, observed during scans with the internal reference. The neteffect of both drifts was corrected by assigning different irradiance values to the internal reference lamp at different times of the season.

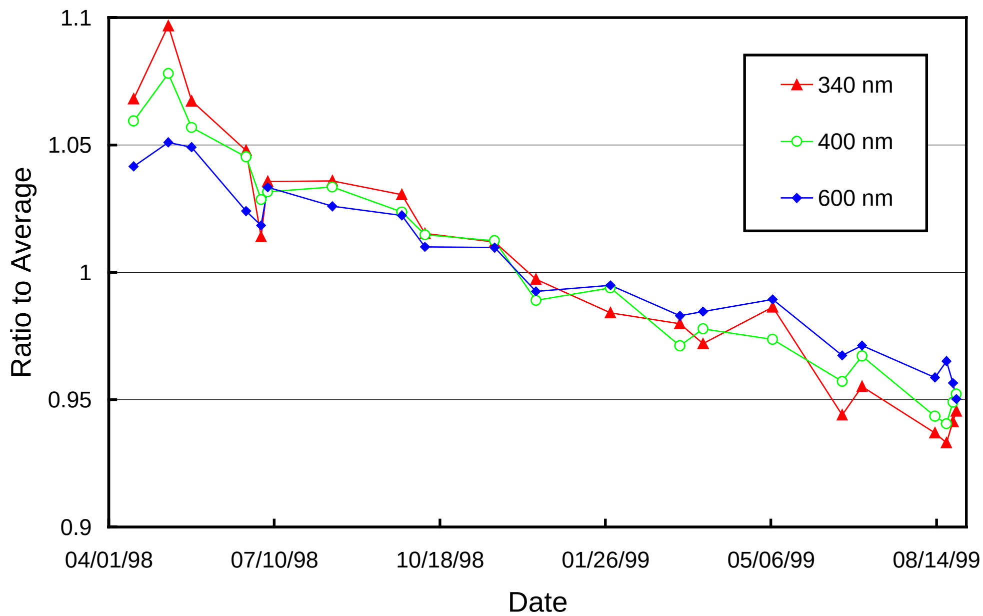

Figure 5.4.5. *Temporal change of PMT current at several wavelengths during measurements of the site standard 200W008.*

The irradiance assigned to the internal lamp in Period 1 was calculated by analyzing seven calibrations with the site irradiance standards, carried out during this period. Absolute scans, which were affected by the loose connection to the internal lamp, were excluded. From each of these calibrations, irradiance values for the internal irradiance reference were calculated, and the mean-irradiance for this period was derived by averaging over the individual calibration functions, according to the procedure outlined in Section 4.2.1.2. The ratio of the standard deviation and average mean-irradiance, both calculated from the seven calibrations, is a useful tool for estimating the variability of the calibrations for this period. As shown in Figure 5.4.6, the standard deviation is usually less than 1% of the average and increases towards shorter wavelengths, reaching 1.9% at 300 nm. The increase towards shorter wavelengths is caused by a change of the system responsivity during Period 1, which is highest at short wavelengths. The consistency of the calibrations is still satisfactory, considering the problem in this period.

The same procedure was also applied to Period 2 (17 useable absolute scans), Period 3 (15 useable scans), and Period 4 (17 useable scans). The standard-deviation-to-average ratio for these periods are generally below 1% and are also shown in Figure 5.4.6.

Figure 5.4.7 shows the ratio of irradiance assigned to the internal reference lamp in Periods 2-4 divided by the irradiance of Period 1. As can be seen, there is a gradual upward drift of the reference irradiances, associated with the gradual dust buildup on the lens. The difference in the reference irradiance between Periods 1 and 4 is about 8-10%. This change is consistent with the combined effect of the drift of the internal lamp (Figure 5.4.4), and the through-the-collector change of the signal when measuring site standards (Figure 5.4.5). Note that the reference irradiance assigned to the internal lamp changed by about 3-5% between Period 1 and Period 2. This change is also visible in solar data. Thus published solar spectral irradiance data at the end of Period 1 (on day 6/30/98) are expected to be too low by 2%, whereas irradiance one day after are high by 2%. This uncertainty of ±2% cannot be avoided unless the season were split into more periods, which would lead to higher uncertainties in the individual mean-irradiances assigned to the internal lamp of the different periods.

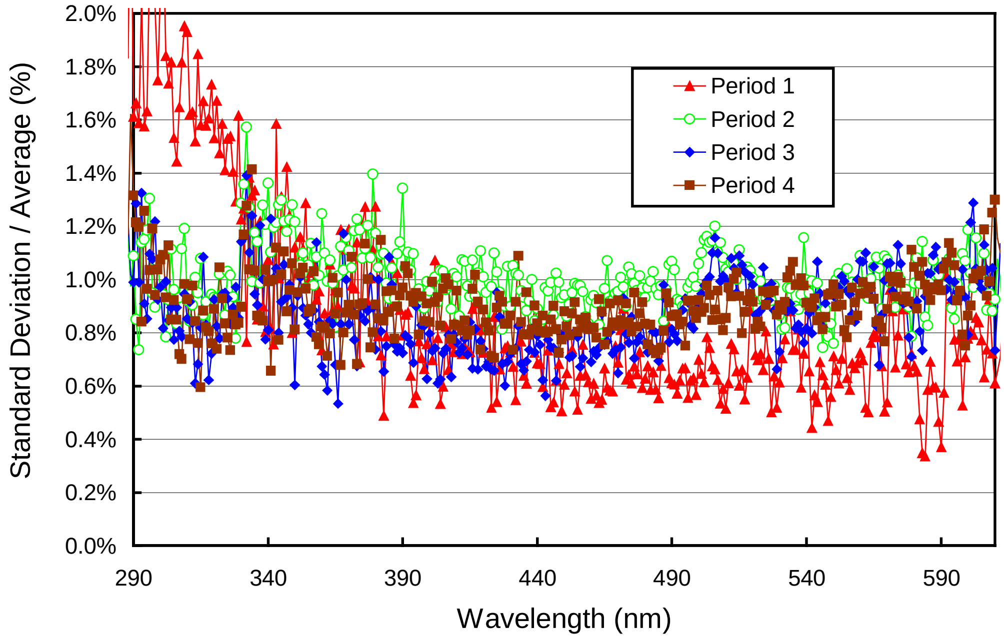

Figure 5.4.6. *Standard deviation to average ratio calculated from the absolute calibration scans of Periods 1-4 .*

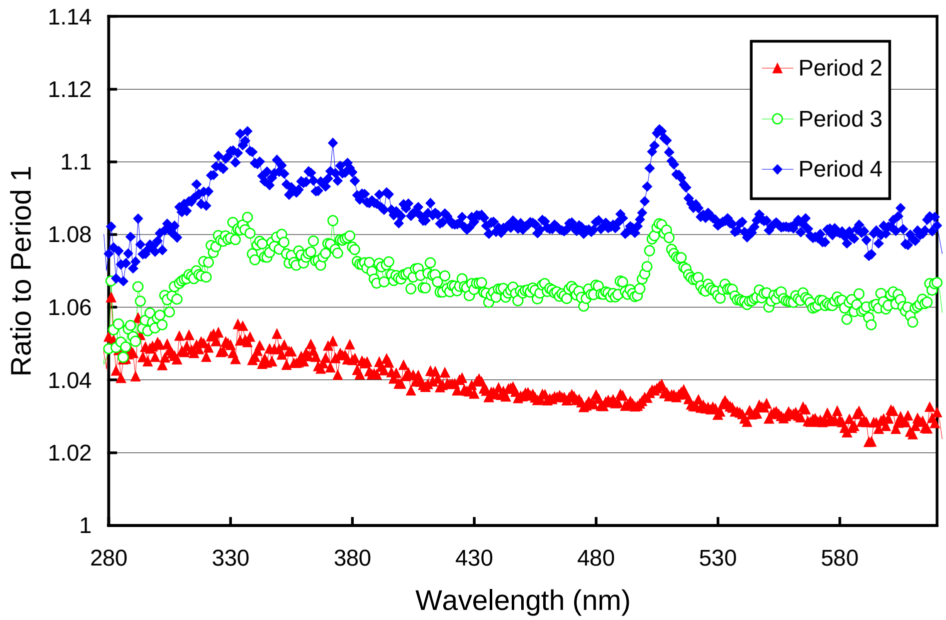

Figure 5.4.7. *Ratio of irradiance assigned to the internal reference lamp in Periods 2-4 divided by the irradiance of Period 1.*

5.4.3. Wavelength Calibration

Wavelength stability of the system was monitored with the internal mercury lamp. As discussed in the introduction to Section 5.4., the wavelength offset during the Ushuaia 1998-99 season changed often between consecutive wavelength scans. Most breaks were caused by power outages. Before and after these abrupt changes, the instrument wavelength was stable. By appropriately adjusting the paring of wavelength and data scans during final data analysis, the problem was corrected and the wavelength accuracy of the published data is therefore not significantly degraded. However, several data scans had to be discarded when no matching wavelength scans were available, reducing the overall number of records in the published dataset.

Figure 5.4.8 shows the differences in the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 492 scans were evaluated. These scans fall in two groups: For 84% of the scans the difference in the wavelength offset to neighboring scans is less than ±0.035 nm and for 72 scans (15%), the change was larger than ± 0.105 nm. Note that the number of scans with a negative change approximately equals the number of scans with a positive change because the wavelength offset was usually manually re-adjusted by the site operator after a break in the wavelength position from a power outage had occurred.

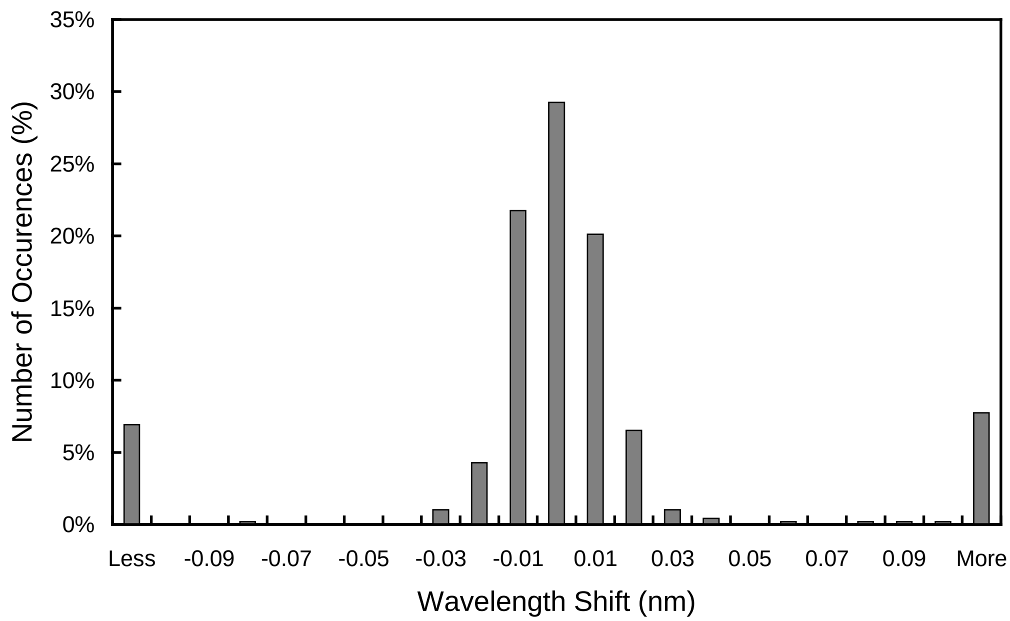

Figure 5.4.8. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The labels of the horizontal axis give the center wavelength shift for each column. The 0-nm histogram column covers the range from -0.005 to +0.005 nm. "Less" means shifts smaller than -0.105 nm; "more" means shifts larger than 0.105 nm.*

After the data was corrected for day-to-day wavelength fluctuations by evaluating the internal scans, 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 heavy line in Figure 5.4.9 shows the resulting correction function applied to the Volume 8 Ushuaia data. The function clearly depends on wavelength, which is caused by non-linearities in 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 5.4.9 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 0.08 nm. As explained in Section 4.2.2, this bias is caused by the different instrument light paths for the internal wavelength scans, and solar measurements.

After the data was wavelength corrected using the shift function described above, the wavelength accuracy was tested again with the Fraunhofer method. The results are shown in Figure 5.4.10 for four UV wavelengths. In contrast to the other sites, where only noontime scans were checked, a total of 4 scans were checked for each day, which explains the higher density of data points in Figure 5.4.10 compared to similar plots for other sites. All scans of a day were also checked whenever the wavelength accuracy was dubious, like for days with power outages. Figure 5.4.10 shows that the residual shifts were generally smaller than ±0.05 nm, independent of time of day. As can be expected, there is more scatter in the 310 nm data in winter due to lower light levels, which reduce the precision of the correlation method. The actual wavelength uncertainty may be a little larger due to possible systematic errors of the Fraunhofer-correlation method (see Section 4.2.2).

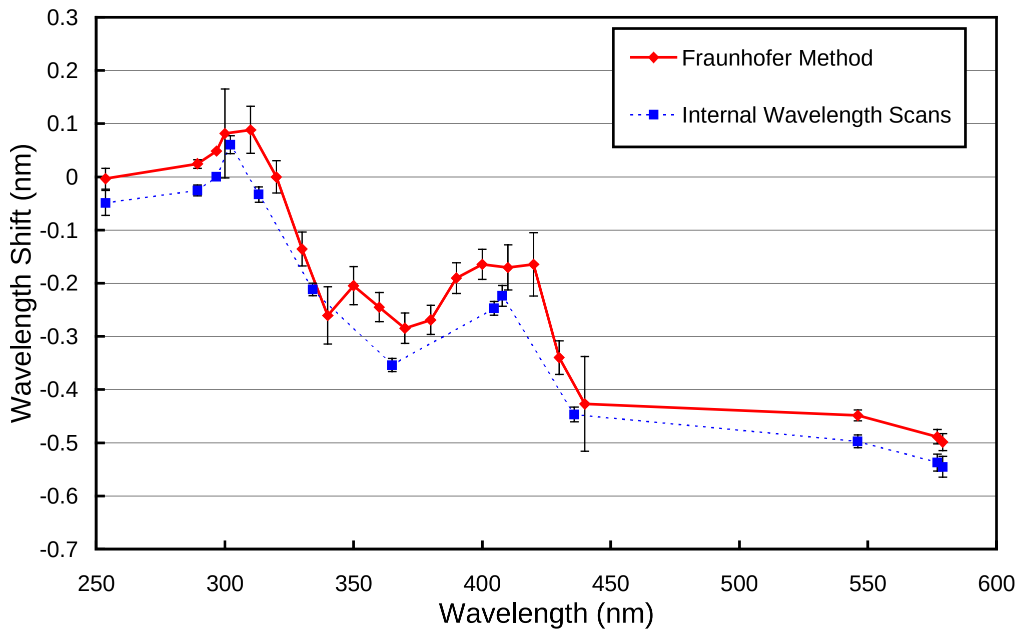

Figure 5.4.9. *Monochromator non-linearity for the Ushuaia 1998-99 season. Heavy line: Correction function calculated with the Fraunhofer-correlation method, applied to correct the Ushuaia Volume 8 data. Thin broken line: Correction function calculated with the method that was historically applied. The offset difference between both methods is 0.08 nm. The error bars are the 1σ standard deviation of the wavelength shift for the season.*

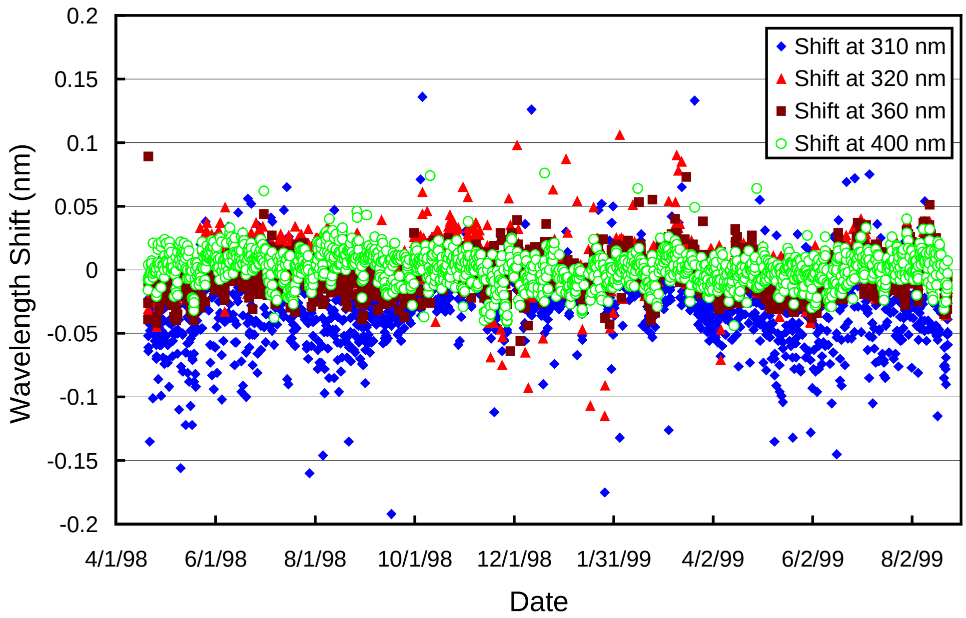

Figure 5.4.10. *Wavelength accuracy check of the final data at four wavelengths by means of Fraunhofer correlation. Measurements at four different times of the day have been evaluated for each day of the season.*

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 5.4.11 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 scale is based on a combination of the Fraunhofer-correlation technique and wavelength-offset determination with internal mercury scans. The peak of the external scans, which have the same light path as solar measurements, agrees approximately with the nominal wavelength of 296.73 nm, whereas the peak of the internal scans is shifted about 0.15 nm to shorter wavelengths. External scans have a bandwidth of about 1.05 nm FWHM, whereas the bandwidth of the internal scan is only 0.74 nm. As external scans have the same light path as solar measurements, they more realistically represent the monochromator bandpass relevant to solar scans. These scans at the start and end of the season are very consistent.

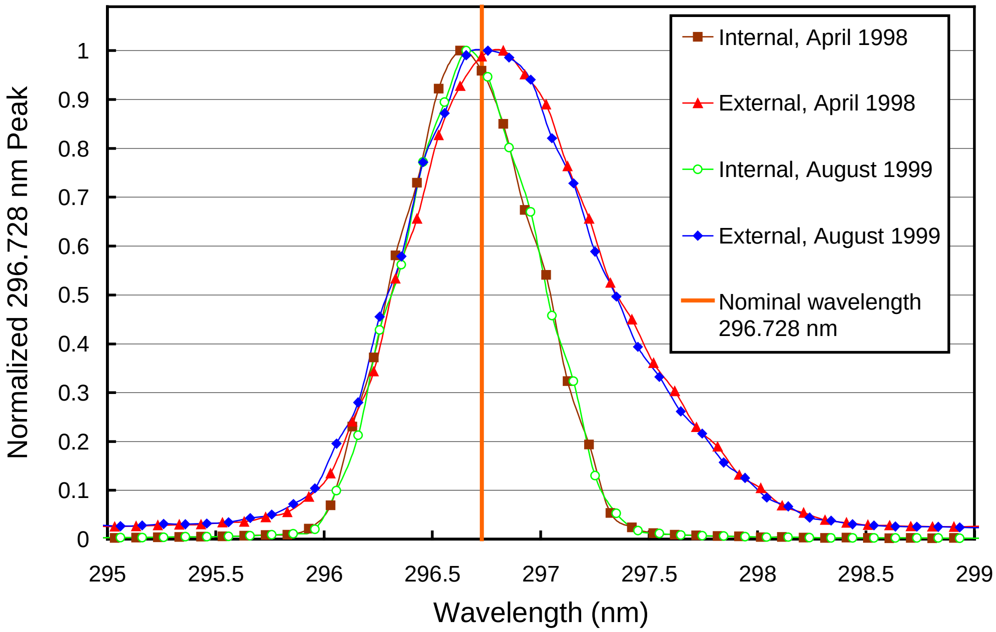

Figure 5.4.11. *The 296.73 mercury line as registered by the PMT from external and internal sources. The wavelength scale is the same as applied for solar measurements, i.e., it is based on a combination of internal scans and the Fraunhofer-correlation method. It is assumed that the wavelength registration of the monochromator did not shift between internal and external scans, which were close in time.*

5.4.4. Missing Data

A total of 22596 scans with SZA smaller than 92° were scheduled to be measured in the Ushuaia Volume 8 season. Of these scans, 21824 (96.6%) were found to be of good quality and are therefore part of the published dataset. Of the missing scans, 226, 38, and 21 were superseded by absolute, wavelength and response scans, respectively. A total of 326 scans were lost because of technical problems. The majority of this loss can be attributed to power failures (92 scans) and—as a consequence to this—changes in the wavelength offset: 111 data scans could not not be paired with an appropriate wavelength scan and were therefore lost. 26 data scans were not started during attempts to recover the wavelength position after power failures. The majority of the 76 scans, which were found to be defective during data analysis, were also affected by the wavelength offset problem. In addition, 60 scans were lost because of full data media or problems with a removeable media drive. 29 scans were lost during the battery change of the uninteruptable power supply. Finally, 91 scans were not measured for various reasons or they were superceeded by system checks of the site operator. A total of 22328 scans are listed in the published databases, including 504 scans with solar zenith angles between 92° and 95°.