5.5. San Diego (10/2/98 – 9/19/99)

The 1998-99 season at San Diego includes the period 10/2/98-9/19/99. In contrast to the other network sites, maintenance and lamp intercomparisons are performed year-round and during operator training. With few exceptions, the system operated normally during the period of Volume 8. In February and March 1999, the shutter got stuck several times before it was replaced on 3/18/99. A total of 99 data scans had to be discarded because of this problem; the accuracy of published data is not affected. All sites standards drifted, some by up to 4%. The effect on the calibration uncertainty is small, however, since the internal irradiance reference lamp was very stable. This allowed establishing the instrument's calibration using absolute scans from a period before the lamps started to drift. Approximately 93% of the scheduled data scans are part of the published dataset; 4% of all scans were lost because of technical problems. The instrument reponsivity drifted by 9% during the season, this drift, however, was corrected during data analysis. Thus published data are not affected.

5.5.1. Irradiance Calibration

The site irradiance standards for the 1998-99 season used in San Diego were the lamps 200W010, 200W020, and M-881. The standard 200W010 was calibrated twice by Optronic Laboratories, in November 1996 and September 1998. Since the latter calibration was immediately before the start of San Diego Volume 8, it was the one used for calibrating the SUV-100 instrument. The lamp 200W020 was introduced for Volume 8 and was also calibrated by Optronic Laboratories in September 1998. The standard M-881 was first calibrated by Optronic Laboratories in August 1995 and recalibrated in September 1998.

In addition to the three site standards, a total of 10 other lamps were used during the season. Some of these standards were later employed at the network sites and the preceding verification at Biospherical Instruments assured that the lamps were correctly calibrated. Other lamps were used previously as site standards and checked after their return. Two lamps (200W016 and 200W022) were stored at Biospherical Instruments after testing and were not used between November 1998 and July 2000. These lamps were not calibrated but they are valuable to track drifts of other standards. As it is unlikely that the lamps change while being archived they preserve the irradiance scale from November 1998 over a long-term period.

Tables 5.5.1. Lamps used at San Diego between 10/1/98 and 9/21/99.

Serial Number	Latest Calibration	Use
200W009	Optronic 9/98	Site Standard Barrow Volume 8
200W010	Optronic 9/98	Site Standard San Diego Volume 8
200W016	no calibration	Long-term reference
200W019	Optronic 9/98	Site Standard McMurdo Volume 9
200W020	Optronic 9/98	Site Standard San Diego Volume 8
200W021	Optronic 9/98	Site Standard South Pole Volume 9
200W022	no calibration	Long-term reference
M-699	Optronic 9/98	Site Standard Barrow Volume 8
M-762	Optronic 9/98	Site Standard Barrow Volume 8
M-763	BSI transfer from M-874	Site Standard South Pole Volume 8
M-764	Optronic 10/92	Site Standard McMurdo Volume 8
M-874	Optronic 9/98	Traveling Standard
M-881	Optronic 9/98	Site Standard San Diego Volume 8

Figure 5.5.1 shows a comparison of all standards that were tested between 10/15/98 and 10/20/98, at the beginning of the San Diego Volume 8 season. The graph is referenced to the traveling standard M-874. All lamps agree to within ±1.5%. This good agreement can be expected as all lamps had been calibrated (or recalibrated) by Optronic Laboratories in September 1998. Unfortunately, a similar comparison at the end of the season was not possible because M-874 was not available during this time. Figure 5.5.2 instead presents a comparison of the standards 200W010 and M-874 performed between November and December 1999. The graph indicates that the site standard 200W010 drifted by 1.5% in the visible against M-874, which itself was proven to be very stable during 1999 (see the introduction to Section 5). With comparisons like this, the drifts of all San Diego site standards could be assessed. The standard 200W020 became brighter by about 2% in the visible between mid-November 1998 and April 1999. Moreover, it was discovered in July 2000 that the lamp was misaligned in its holder. Since it is unknown when the misalignment occurred, the lamp was not used for calibration of the spectroradiometer after 11/19/98 (On this day, the lamp still agreed nicely with the other standards). The third site standard, M-881, became brighter by approximately 3-4% during the Volume 8 season and this drift continued into next year. The lamp was therefore not used to calibrate final data.

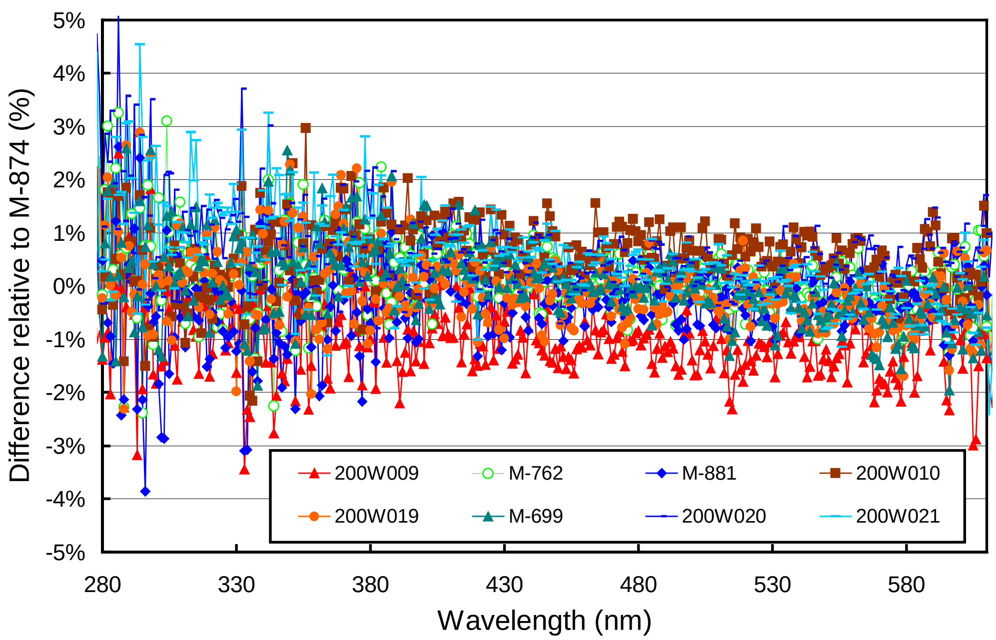

Figure 5.5.1. *Comparison of various lamps, implementing the network instrument in San Diego at the beginning of the Volume 8 season.*

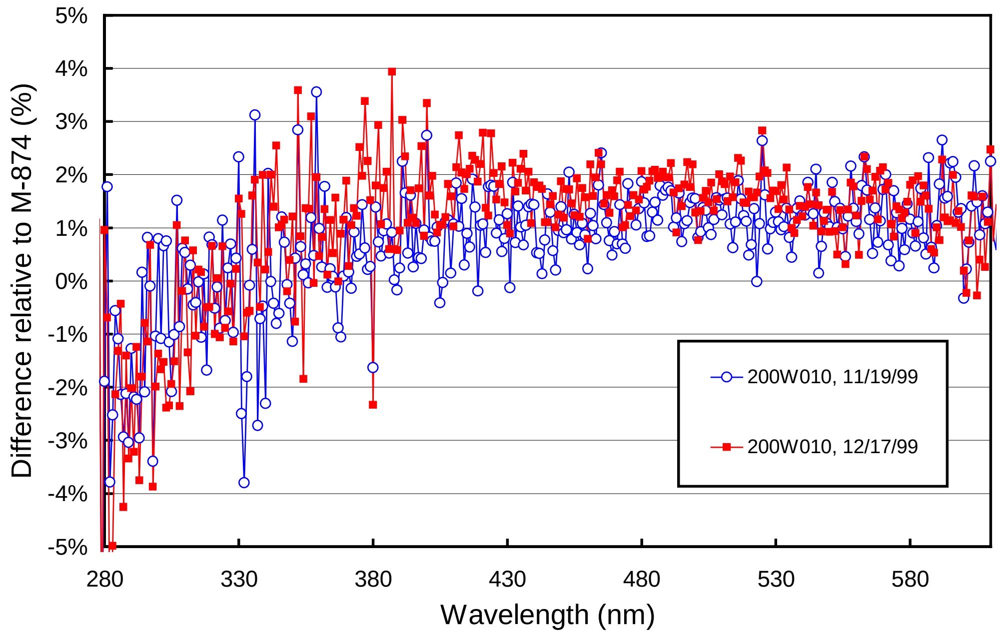

Figure 5.5.2. *Comparison of standards 200W010 and M-874. The absolute scan with lamp M-874 was performed on 12/3/99. The good agreement of the two absolute scans with 200W010 conducted on 11/19/99 and 12/17/99 indicates that the system was very stable during this period. Hence, the comparison is valid, although the lamps were not operated on the same day, as it is usually done.*

5.5.2. Instrument Stability

The stability of the spectroradiometer in San Diego was primarily monitored with the daily response scans of the internal irradiance reference. The stability of this lamp is primarily monitored with the TSI sensor, which is independent from monochromator and PMT drifts. Figure 5.5.3 shows changes in TSI readings and PMT currents at 300 and 400 nm, derived from the daily response scans of the San Diego 1998-99 season. The TSI measurements indicate that the internal reference lamp was stable to within ±1.5%. Because of the good stability only one irradiance spectrum was assigned to the lamp for the whole season.

The PMT currents at 300 and 400 nm during response scans indicate that the instrument responsivity decreased by about 8-9% during the season, approximately independent of wavelength. This change was also found by analyzing the PMT-currents during measurements of the site standard 200W010, after the drift of the standard has been corrected. This confirms that the responsivity change is not due to changes in the instrument's fore optics (Changes in the transmission of the collector cannot be assessed with the internal lamp). Note that the drift in instrument responsivity does not affect solar data because the daily response scans are not performed exclusively for monitoring drifts, but also for correcting these drifts. Day-to-day changes, which would affect solar data, are below 0.5%.

Due to the drift of all San Diego site standards in 1999, absolute scans after 11/21/98 were not used to determine the calibration of the internal irradiance reference lamp. Although this excludes the majority of absolute scans performed, this is justified because of the good stability of the internal lamp throughout the season. One alternative to this approach would have been to correct the drift of 200W010 and process the corrected absolute scans performed with this lamp during the whole season. Our analysis indicates that the results from both approaches are virtually identical. We decided to implement the first method, which eliminates recalibration uncertainties of 200W010.

From each of the eight calibrations with M-874, 200W010, and 200W020 performed before 11/21/98, irradiance values for the internal lamp were calculated. 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, calculated from the 8 calibrations, is a useful tool for estimating the variability of the calibrations. As shown in Figure 5.5.4, the standard deviation is about 0.6% of the average in the visible and increases to 1.5% towards shorter wavelengths.

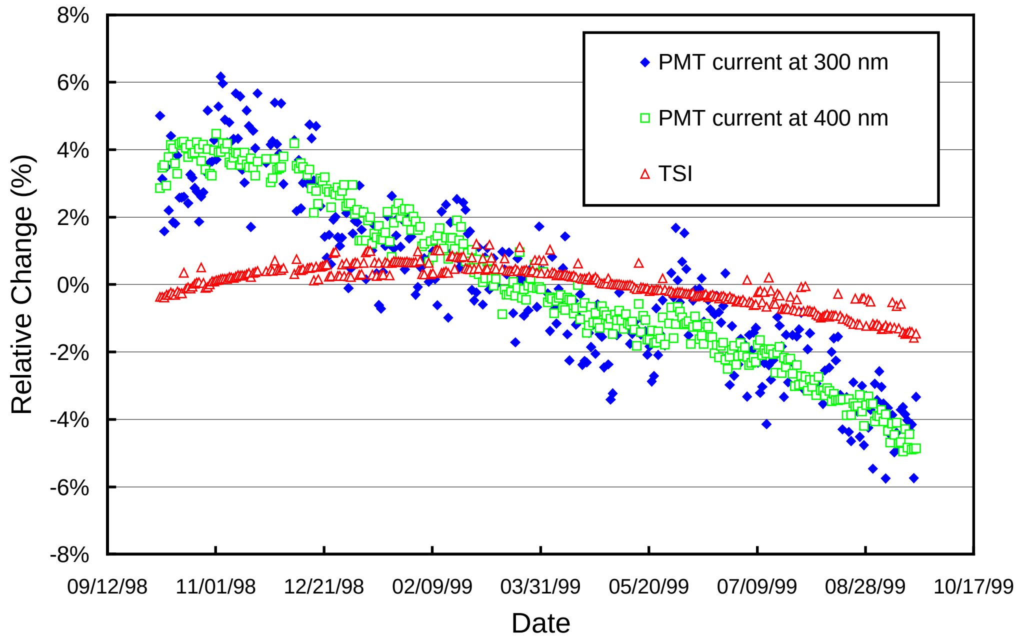

Figure 5.5.3. *Time-series of PMT current at 300 and 400 nm, and TSI signal during measurements of the internal irradiance reference lamp during the San Diego 1998-99 season. The data is normalized to the average value of the whole season.*

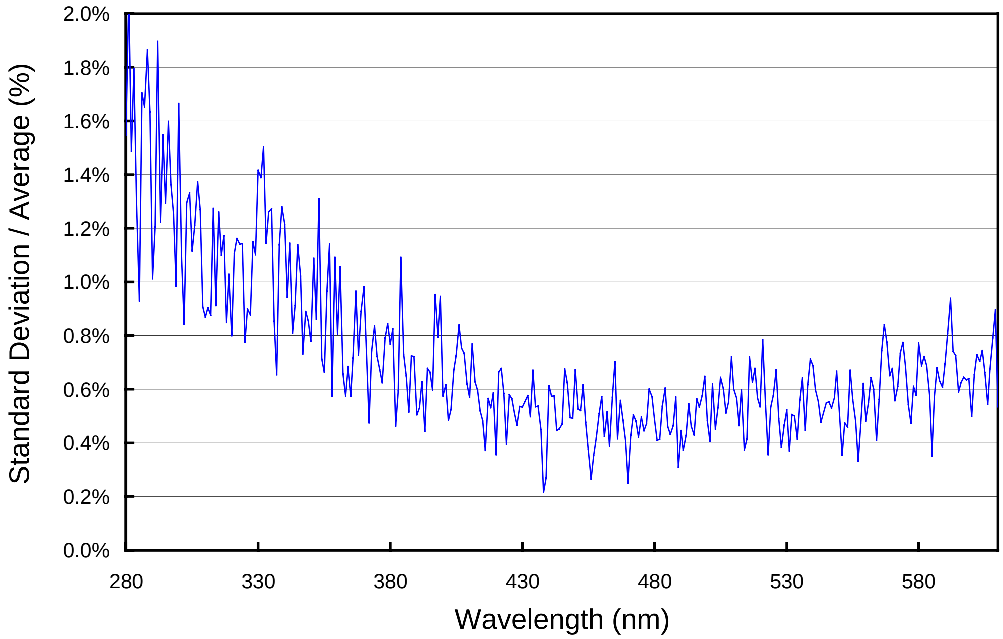

Figure 5.5.4. *Ratio of standard deviation and average calculated from the absolute calibration scans used to establish the calibration of the San Diego spectroradiometer for the 1998-99 season.*

5.5.3. Wavelength Calibration

Wavelength stability of the system was monitored with the daily internal mercury lamp. Information from the 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 5.5.5 shows the differences in the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 345 scans have been evaluated. For 73% of the days, the change in offset is smaller than ±0.025 nm; for 97% of the days the shift is smaller than ±0.055 nm. The offset-difference is larger than ±0.1 nm for six scans (1.7%) only. Due to a missing instrument log-file, a wavelength calibration could not be established for 33 data scans from 2/26/99. Data from the affected period are not published. All other break-points in the wavelength offset were carefully inspected and when dubious, further checked and corrected with the Fraunhofer correlation method.

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 5.5.6 shows the resulting correction function that was applied to the Volume 8 San Diego data. The function clearly depends on wavelength, which is caused by inherent 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 5.5.6 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 0.11 nm. As explained in Section 4, this bias is caused by the different light paths for internal wavelength scans and solar measurements.

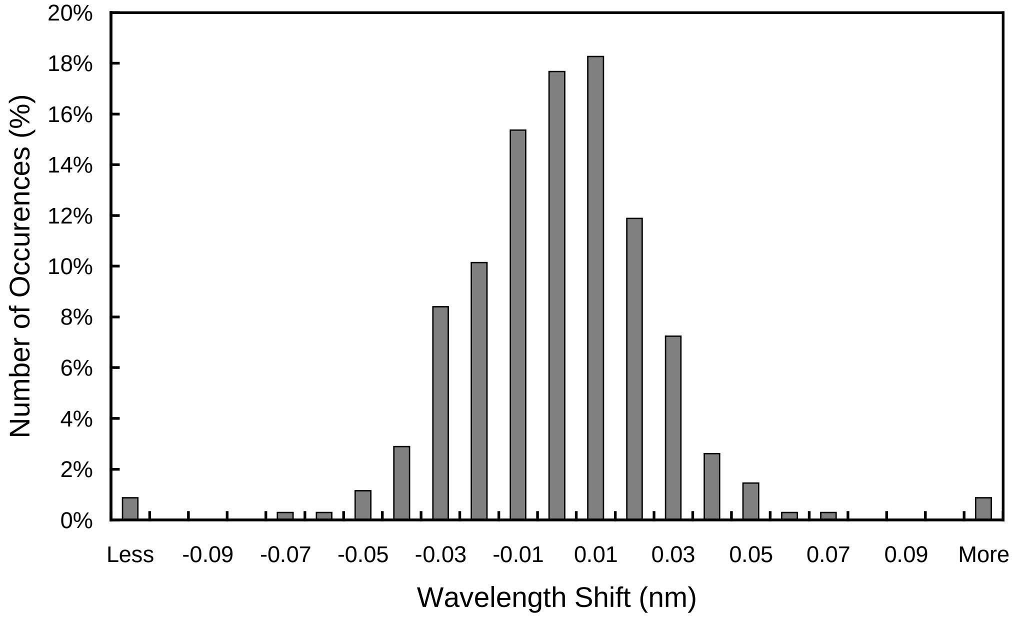

Figure 5.5.5. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. The 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more" means shifts larger than 0.105 nm.*

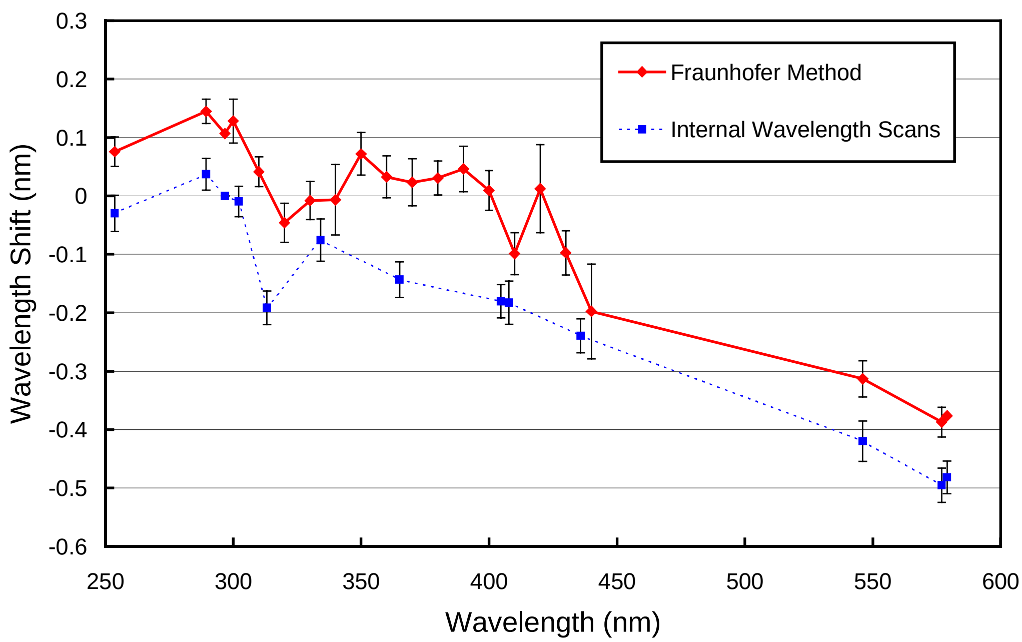

Figure 5.5.6. *Monochromator non-linearity for the San Diego 1998-99 season. Solid line: Correction function calculated with the Fraunhofer-correlation method, applied to correct the San Diego Volume 8 data. Broken line: Correction function calculated with the method that was historically applied. The offset difference between both methods is 0.11 nm. The error bars show the 1σ standard deviation of the wavelength shift for the season.*

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 5.5.7 for four UV wavelengths. The residual shifts for wavelength above 300 nm are generally smaller than ±0.1 nm. There is also some systematic bias: Between the beginning of the season and end of February 1999, residual wavelength shifts are on average about 0.045 nm, approximately independent of wavelength. Shifts drop to about –0.025 nm between March and April 1999, and are about 0.02 nm thereafter. A possible reason for this trend is a change in the offset between the instrument's internal wavelength scale (as measured with the mercury lamp) and the through-the-collector wavelength scale (as determined with the Fraunhofer correlation method). Theoretically, this trend could have been diminished by choosing different tables for the monochromator non-linearity correction for different periods of the season. This was not implemented because the cause of the trend is unknown, and no obvious break-points in the time series can be identified. The somewhat increased wavelength uncertainty is still within the specifications (see Table 2.1, Section 2).

Figure 5.5.7 also reveals more scatter at 300 nm than at longer wavelengths. This can be expected due to the low solar irradiance and comparatively high noise level at 300 nm. The wavelength stability is not worse at this wavelength; yet the correction algorithm is less precise.

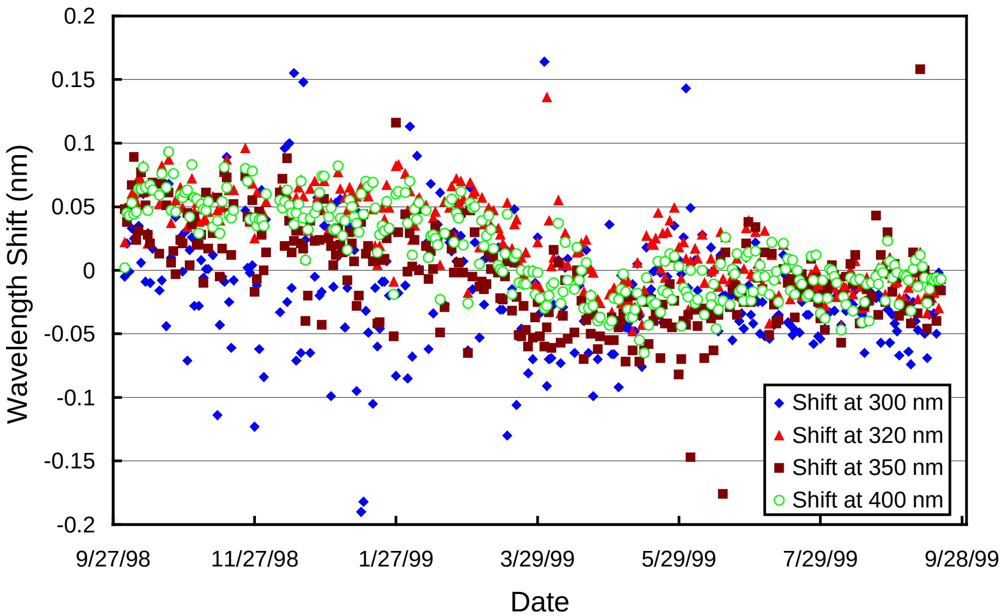

Figure 5.5.7. *Check of the wavelength accuracy of the final data at four wavelengths by means of Fraunhofer correlation. The noontime measurement has been evaluated for each day of the season.*

A comparison of data from internal and external mercury scans is presented for all sites in order to show the difference in the slit functions of the instruments for both configurations. Since no external scans were performed during the Volume 8 San Diego season, Figure 5.5.8 shows measurements from the Volume 7 period. As can be seen, the difference between internal and external scans is very consistent over time. We therefore assume that the functions were similar during the Volume 8 period. The peak of external scans is shifted about 0.10 nm towards longer wavelengths, compared with the internal peak. External scans have a bandwidth of about 1.04 nm FWHM, whereas the bandwidth of the internal scan is only 0.8 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 the start and at the end of the season are very consistent.

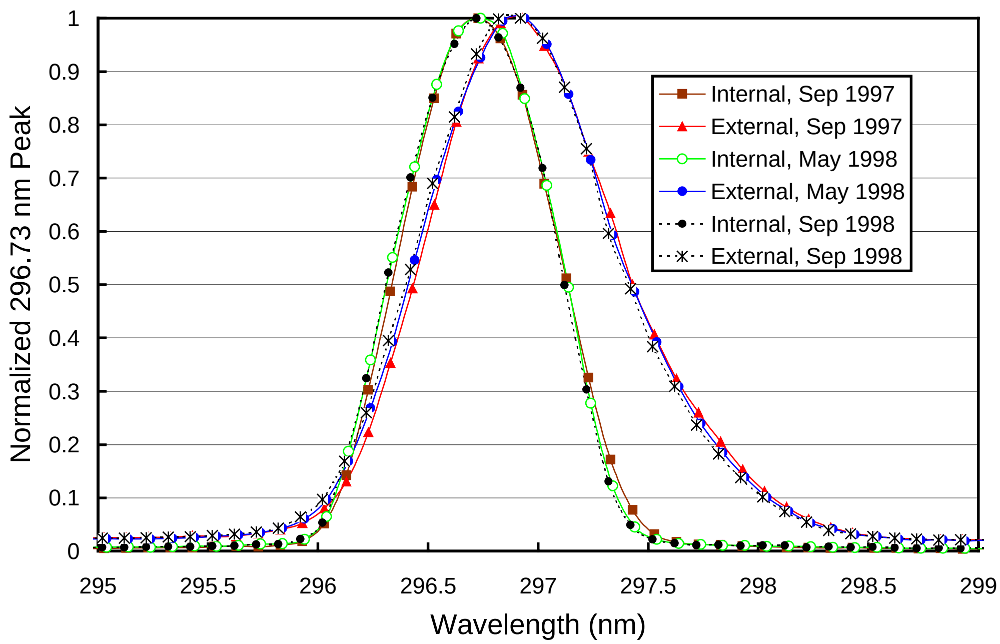

Figure 5.5.8 *The 296.73 mercury line as registered by the PMT from external and internal sources. Data is from the Volume 7 San Diego season.*

5.5.4. Missing Data

A total of 17563 data scans with SZA smaller than 92° were scheduled to be measured during the San Diego Volume 8 season. Of these scans, 16346 (93.1%) were found to be of good quality and are therefore part of the published dataset. Of the missing data scans, 378 and 52 were superseded by calibrations activities and wavelength scans, respectively. The number of calibration scans performed in San Diego is relatively high because of the large number of lamps evaluated (see Section 5.5.1) and the lamp scans performed during the CUCF lamp intercomparison that took place between December 4-6, 1998 (see introduction to Section 5).

During site operator training 77 data scans were missed. A total of 107 data scans scheduled for the days 11/22/98, 3/17/99, 3/18/99, 5/27/99, and 5/28/99 were lost when the system was not returned to the automatic scanning mode after operator intervention. 252 scans were lost because data was not recorded correctly by a peripheral hard disk drive. In addition, 110 data scans were either corrupted or incomplete and were therefore not processed. Because of a jammed shutter, 99 scans were either found to be defective or were not measured when the system was switched off for repair. When defective fans of the PMT cooler assembly were replaced, 53 scans were lost. During general service, including replacement of the peripheral hard disk drive, 47 scans were missed. Finally, a total of 42 scans was lost due to various, other, or unknown reasons. A total of 16577 scas are in the published databases, including 231 scans with solar zenith angles greater than 92°.