5.2. Palmer Station (3/23/03 – 5/19/04)

The 2003-2004 season at Palmer Station is defined as the period between the site visits in 2003 (3/17/03 – 3/24/03) and 2004 (5/19/04 – 6/4/04). Season opening absolute calibrations were performed on 3/22/03 and 5/20/04, respectively. Volume 13 solar data comprise the period 3/23/03 – 5/19/04. Measurements during the season were affected by some technical problems, which are listed below. These problems were addressed during data processing and their impact on the quality of published data is small.

- **Drift and failure of internal lamp**
  The internal reference lamp exhibited an excessive drift of 10% per month in the UV and became very unstable after 7/1/03. It was replaced on 7/23/03. The new lamp was very stable between 7/28/03 and the end of the season. Irradiance spectra assigned to the first lamp were frequently adjusted to correct for the lamp's drift. This procedure could not be applied when the lamp started to fluctuate erratically. Solar measurements between 5/28/03 and 7/23/03 were paired with a scan of the internal lamp measured on 5/28/03. The procedure is further explained below and is acceptable since calibrations with 200-W standards indicated good stability of the instrument during the problematic period.

- **Increased noise**
  Signal noise was increased during the periods 4/12/03 – 5/1/03 and 9/15/03 – 10/2/03, causing some reduction of the detection limit. The problem disappeared when the system ground was disconnected on 10/2/03.

- **Failure of temperature controller**
  The regulator of the roofbox temperature failed on 3/23/04 and was replaced on 3/31/04. Temperatures remained unstable until the new controller was programmed on 4/2/04. The temperature during the affected period was low by approximately 5°C. The impact on solar data is small since temperature controllers for monochromator and PMT (i.e. the most temperature sensitive components of the system) worked without problems.

- **Reduced wavelength range**
  The wavelength range of solar scans was reduced between 10/7/03 and 11/8/03. Data from the spectral integral between 342.5 and 347.5 nm are not available for this period.

- **Time error**
  The GPS unit changed the computer time backward by one day on 5/11/03. Data measured on 5/10/03 were overwritten and are therefore not available.

The Volume 13 season at Palmer resulted in a total of 21288 solar scans. Only 1% of scans was lost due to technical problems.

5.2.1. Irradiance Calibration

The site irradiance standards for 2003-2004 were the lamps 200W007, M-765, and M-700. Lamp M-764 was used as the traveling standard at the beginning and end of the season. The lamp was calibrated by Optronic Laboratories in March 2001.

Lamp 200W007 has an irradiance calibration from Optronic Laboratories from November 1996. Lamp M-765 has an Optronic Laboratories calibration from 1992 and has been in use at Palmer Station since 1992. The lamp was recalibrated with the previous traveling standard M-874 using data from the Volume 9 opening calibrations. Lamp M-700 was calibrated in a similar fashion as lamp M-765; the irradiance calibration was transferred from the traveling standard M-874 using absolute scans of both lamps from days 5/11/99 and 5/12/99. The calibrations of all three site standards were the same as in Volumes 10 – 12.

Figure 5.2.1 shows the Volume 13 season opening calibrations. All site standards agreed on the ±1% level with M-764. A similar comparison performed at the end of the season is shown in Figure 5.2.2. Lamps M-700 and M-765 agree with M-764 to within ±1%; the difference between lamps 200W007 and M-764 is slightly larger. In addition to season start and end evaluation, all three site standards were compared with each other on four occasions during the season. At all events, lamps M-700 and M765 agreed to within ±0.5%, and the results from lamp 200W007 differed by 1-2%. This difference is still within in the uncertainty of lamp calibrations and no adjustments were applied.

During cleaning of lamp M-700 on 12/20/03, the bulb was inadvertently moved out of position and repositioned as closely as possible. Comparisons of M-700 with M-765 on 10/10/03 and 3/25/04 did not indicate any change in the calibration of M-700, indicating that the misalignment was adequately corrected.

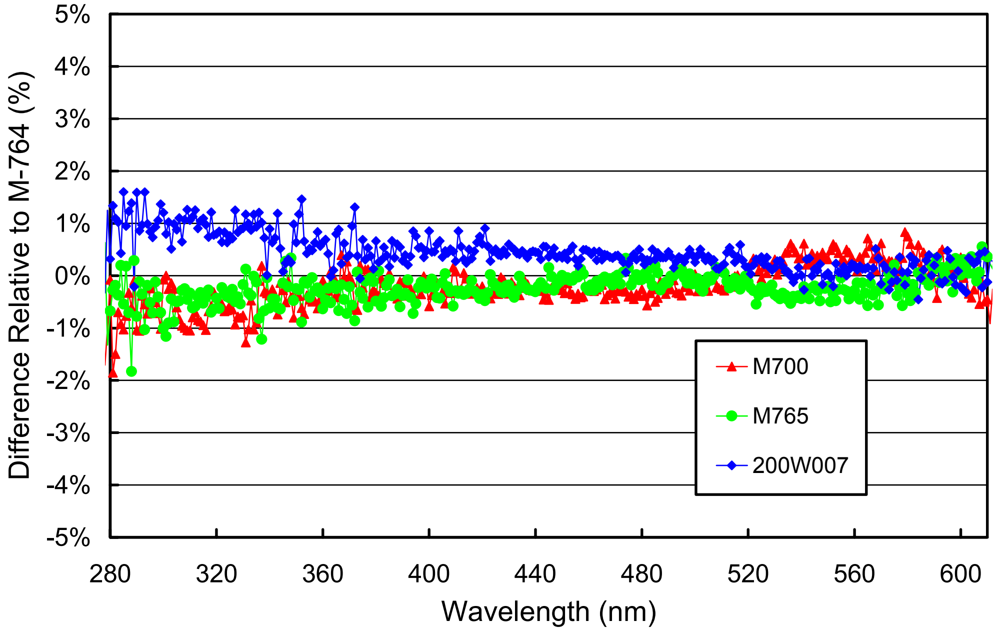

Figure 5.2.1. *Comparison of Palmer lamps 200W007, M-700, and M-765 with the BSI traveling standard M-764 at the beginning of the season (3/22/03).*

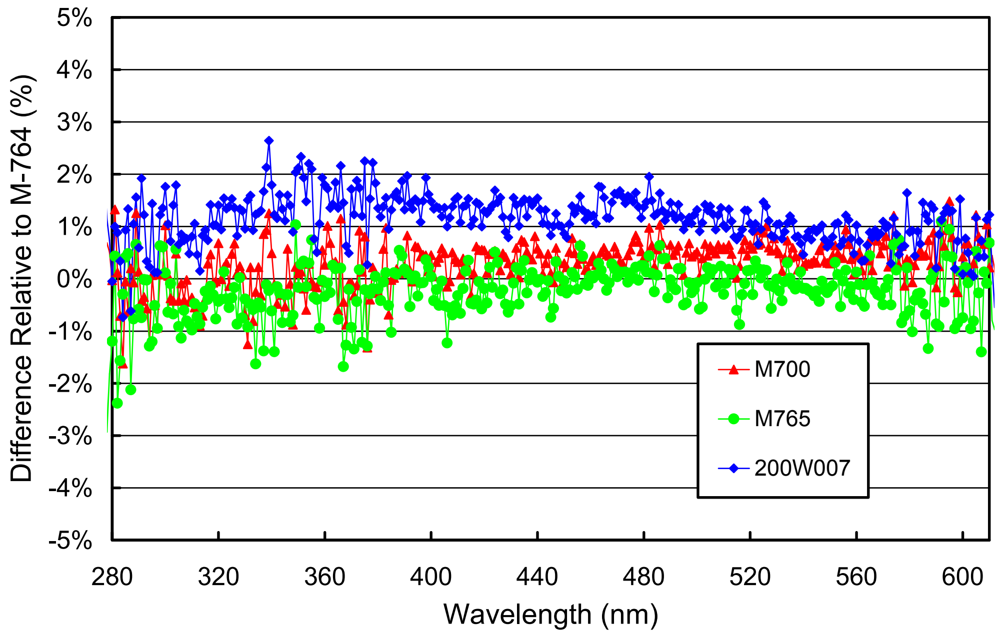

Figure 5.2.2. *Comparison of Palmer lamps 200W007, M-700, and M-765 with the BSI traveling standard M-764 at the end of the season (5/20/04).*

5.2.2. 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 itself is monitored with the TSI sensor, which is independent from possible monochromator and PMT drifts. By logging the PMT currents at several wavelengths during response scans, changes in the instrument responsivity can be detected.

Figure 5.2.3 shows changes in TSI readings and PMT currents at 300 and 400 nm, derived from daily response scans of the Palmer 2003/04 season. TSI measurements indicate that the internal lamp exhibited an excessive change of approximately 10% per month starting immediately after the site visit. PMT currents at 400 nm followed this trend nicely, indicating that monochromator and PMT were stable. The lamp became were unstable after 7/1/03. The lamp was properly seasoned and we do not believe that drifts and instabilities were caused by incorrect operating conditions. We have seen similar drifts at other sites during the last two years and we believe that that recently purchased lamps have quality problems.

The large drift required frequent changes of the irradiance spectrum assigned to the lamp. A total of seven different calibrations were consequently calculated for the period 3/23/03 – 7/24/03. However, calibrations performed during Periods P3A and P4 (6/8/03 – 7/24/03) were not used due the lamp's instability. Solar measurements from these periods were calibrated with the calibration spectrum of Period P3 and paired with a scan of the internal lamp measured on 5/28/03. Thus, the system was made to believe that the internal lamp was stable from 5/28/03 onward. This approach is only feasible if other system components do not drift. Analysis of absolute scans suggested that this was the case.

The defective lamp was replaced on 7/23/03. Figure 5.2.3 indicates that the new lamp (Lamp #2) was stable to within ±1.5% for the remainder of the season.

Figure 5.2.4. shows ratios of irradiance spectra assigned to Lamp #1 in Periods P1a – P4 relative to the spectrum assigned in Period 1. Spectra of periods P1A, P2A and P3A were calculated by interpolation. The lamp's irradiance changed by 18% at 280 nm and 8% at 600 nm. Figure 5.2.5 shows a similar analysis for irradiance spectra assigned to Lamp #2. Table 5.2.1 gives an overview of calibration periods.

The standard deviation of the individual spectra contributing to the average spectrum assigned to each calibration period were calculated. Figure 5.2.5 shows the ratio of the standard deviation and average spectra. The ratios are useful for estimating the variability of the calibrations with a calibration period. The relative standard deviation is usually less than 1.5% for wavelengths in the UV-A and visible, and increases slightly towards shorter wavelengths. One exception is Period P2, which is based on two absolute scans only.

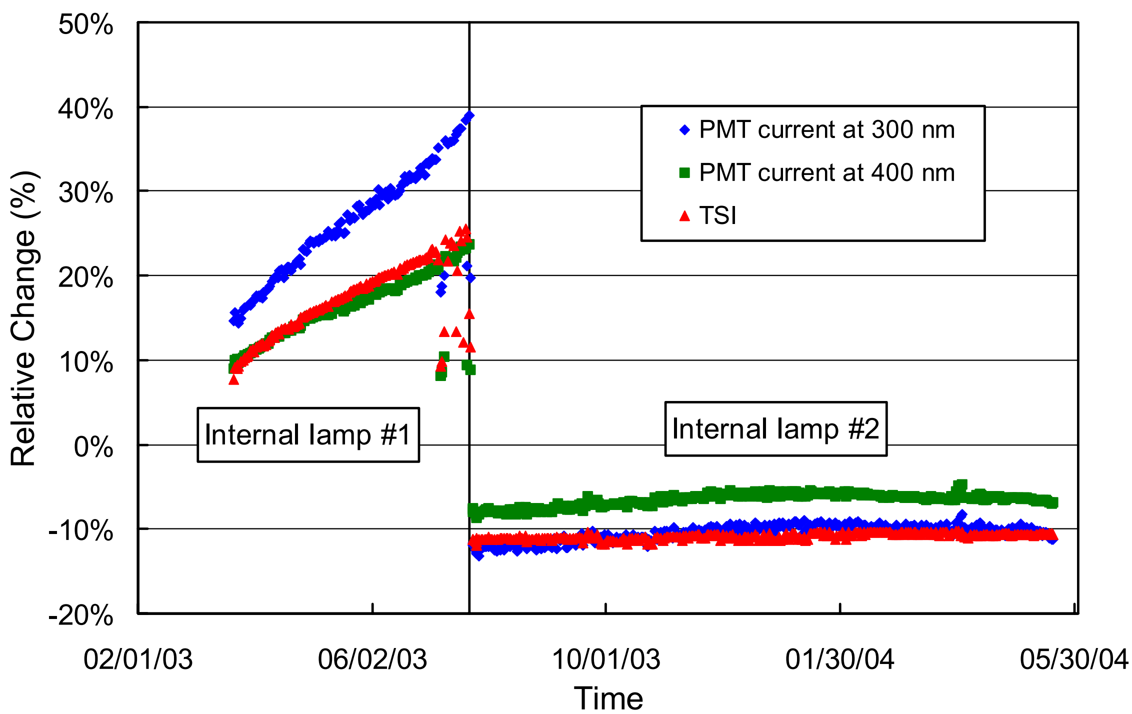

Figure 5.2.3. *Time-series of PMT current at 300 and 400 nm, and TSI signal during measurements of the internal lamp during the Palmer 2003/04 season. Internal lamp #1 exhibited a larger drift, became unstable on 7/1/03, and was replaced on 7/23/03. The data is normalized to the average of all periods.*

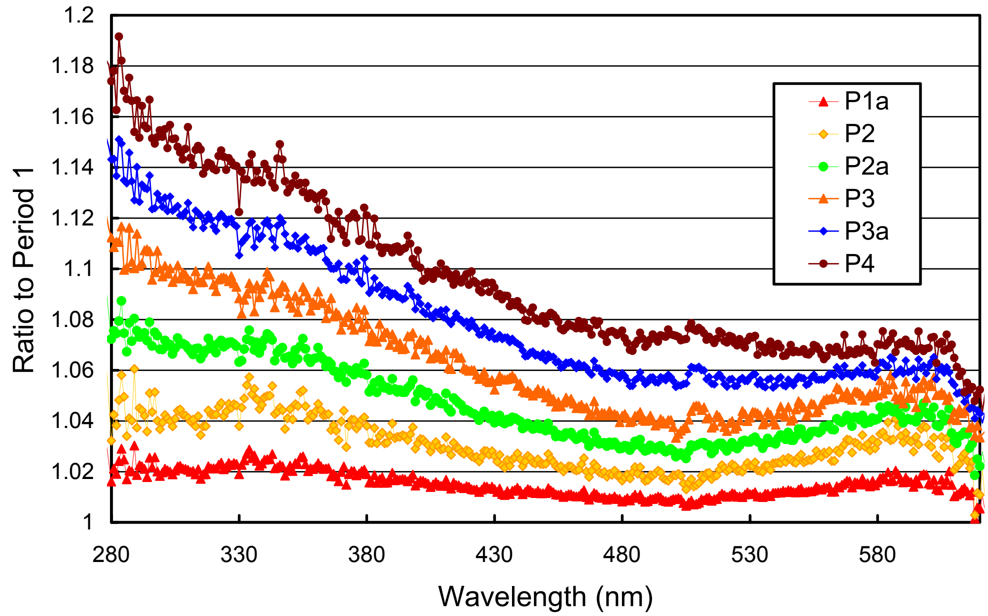

Figure 5.2.4. *Ratios of irradiance spectra assigned to the Internal Lamp #1 in Periods P1a – P4 relative to Period P1.*

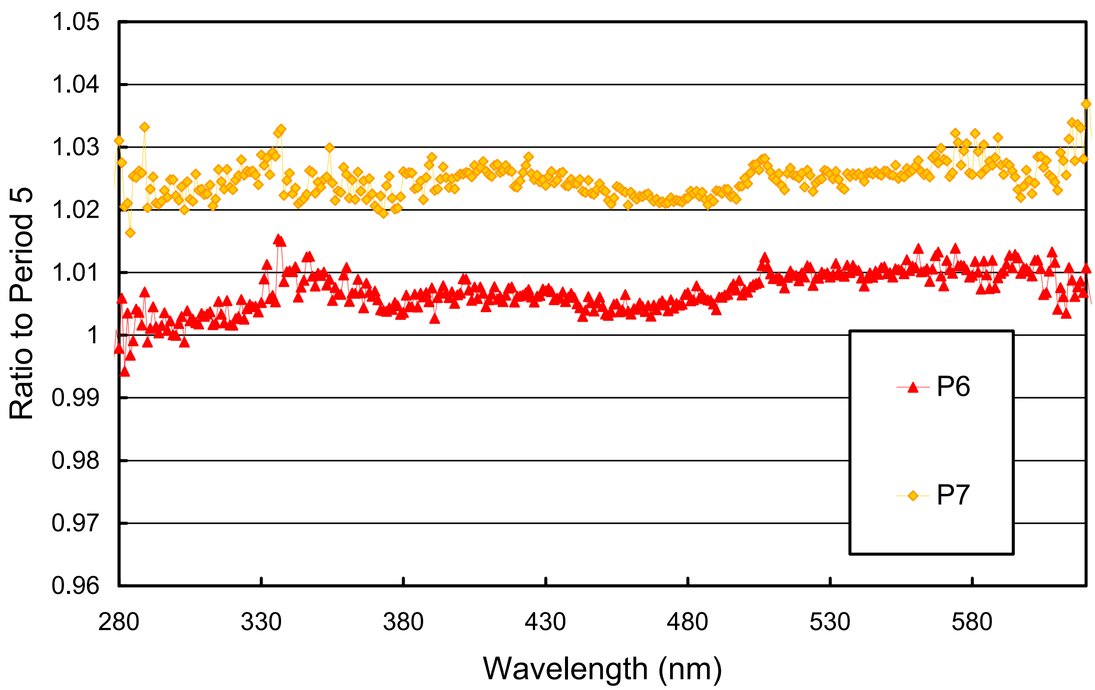

Figure 5.2.5. *Ratios of irradiance spectra assigned to the Internal Lamp #2 in Periods P6 and P7 compared to Period P5.*

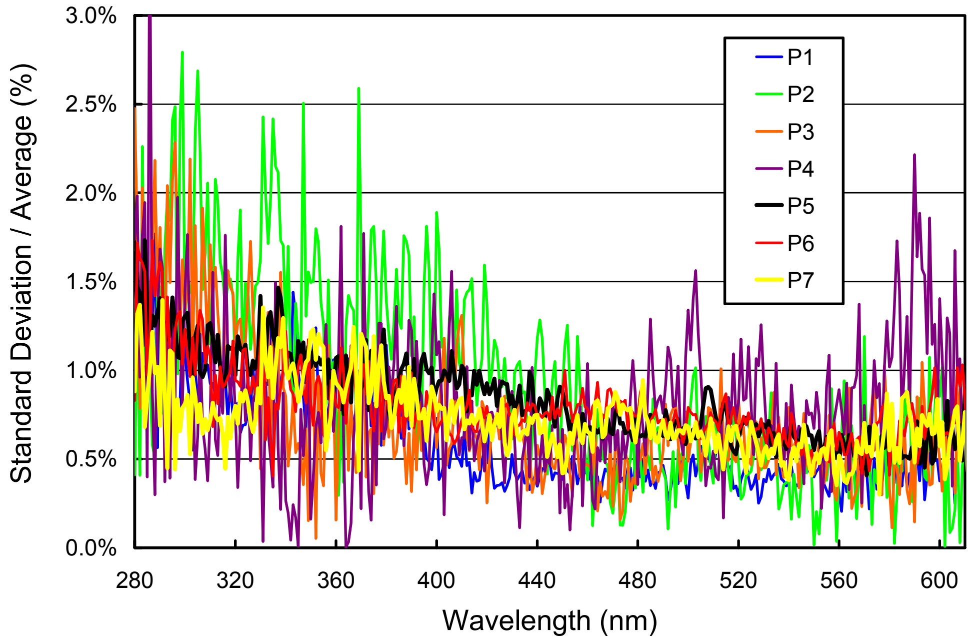

Figure 5.2.6. *Ratio of standard deviation and average calculated from the absolute calibration scans.*

Table 5.2.1: Calibration periods for Palmer Volume 13 data

Period name	Period range	Number of Absolute scans	Remarks
P1	03/23/03 – 03/27/03	7	
P1A	03/28/03 – 04/05/03	-	Interpolation
P2	04/06/03 – 04/28/03	2	
P2A	04/29/03 – 05/03/03	-	Interpolation
P3	05/04/03 – 06/07/03	3	Applied to period: 05/04/03 – 07/24/03
P3A	06/08/03 – 06/14/03	-	Not used
P4	0615/03 – 07/24/03	2	Not used
P5	07/25/03 – 12/31/03	13	
P6	01/01/04 – 05/14/04	12	
P7	05/15/04 – 05/20/04	8	

5.2.3. 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 5.2.7 shows differences in the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 466 scans were evaluated. For 96.1% of the days, the change in offset was smaller than ±0.025 nm; for 98.7% of the days, the change in offset was smaller than ±0.055 nm. Four scans had shifts of larger than ±0.1 nm, and appropriate corrections were applied.

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. Results indicated a small change of the monochromator's wavelength mapping over the season, requiring three different correction functions (Figure 5.2.8). After the data was wavelength corrected using these functions, the wavelength accuracy was tested again with the Fraunhofer method. The results are shown in Figure 5.2.9 for four UV wavelengths. The residual shifts are generally smaller than ±0.05 nm. Shifts at 310 nm show several outliers between April and August when the correlation algorithm is hampered by low radiation levels.

Although data from the external mercury scans do not have a direct influence on the data products, they are part of our instrument characterization routine. Figure 5.2.10 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 0.99 nm FWHM; the bandwidth of the internal scan is only 0.74 nm. Internal scans of both periods are shifted by about 0.07 nm to shorter wavelength with respect to their external counterparts. Since external scans have the same light path as solar measurements, they more realistically represent the monochromator bandpass relevant for solar scans.

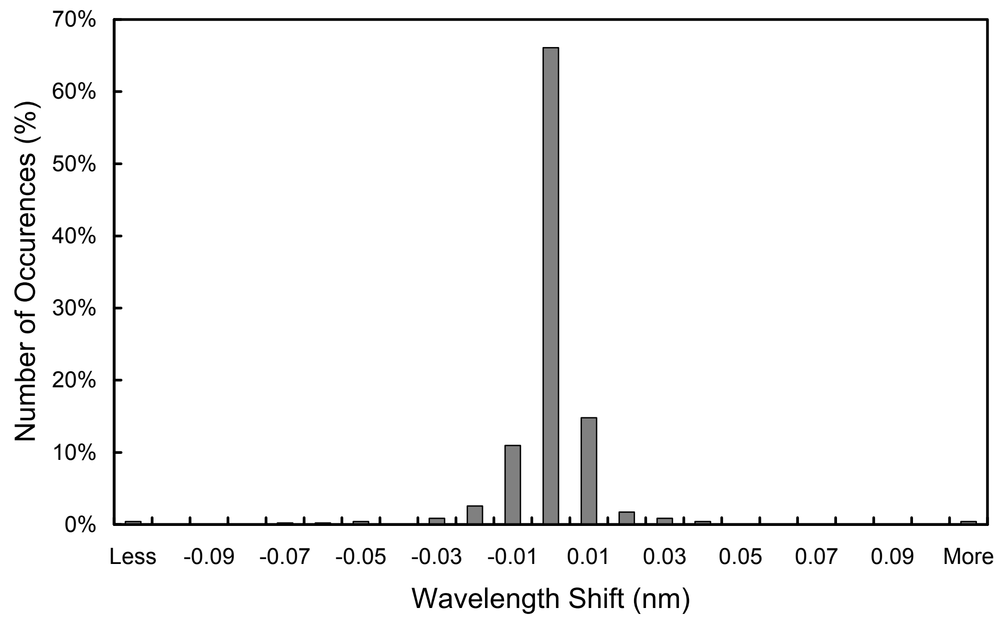

Figure 5.2.7. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. Thus the 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more" means shifts larger than 0.105 nm.*

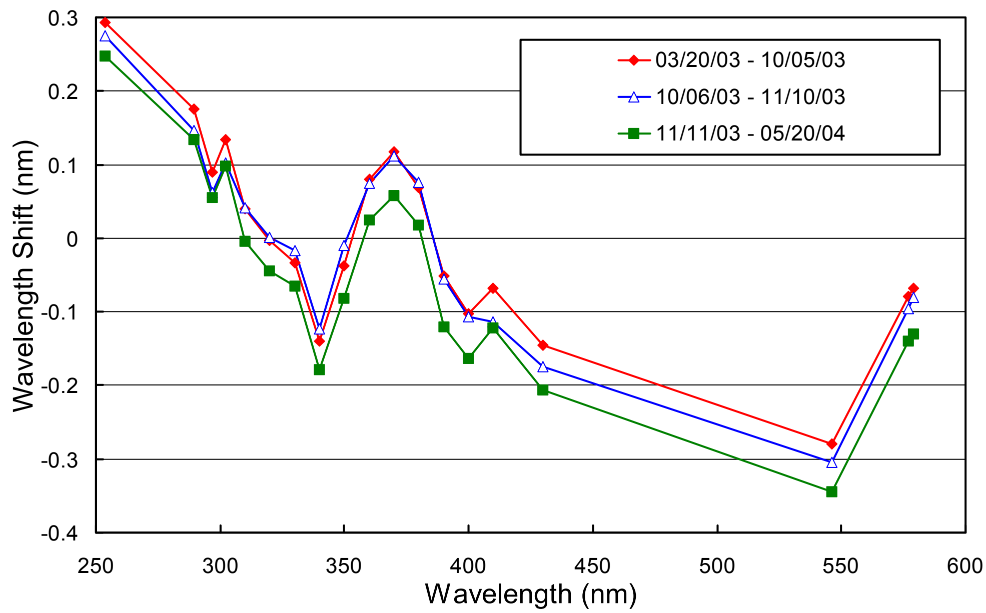

Figure 5.2.8. *Monochromator mapping functions for the Palmer 2003/04 season.*

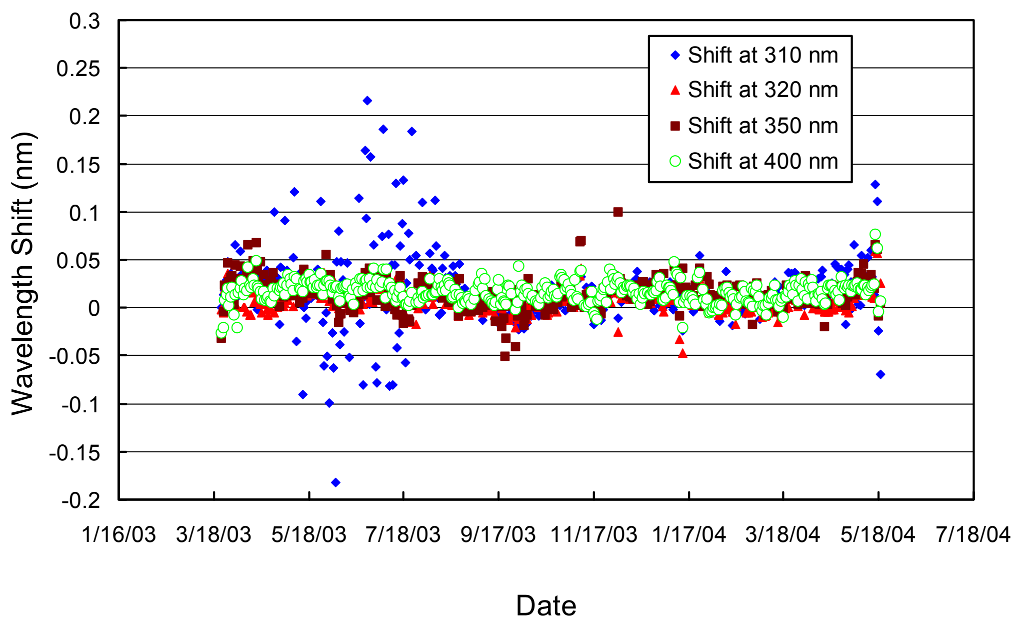

Figure 5.2.9. *Wavelength accuracy check of the final data at four wavelengths by means of Fraunhofer correlation. The noontime measurement has been evaluated for each day of the season.*

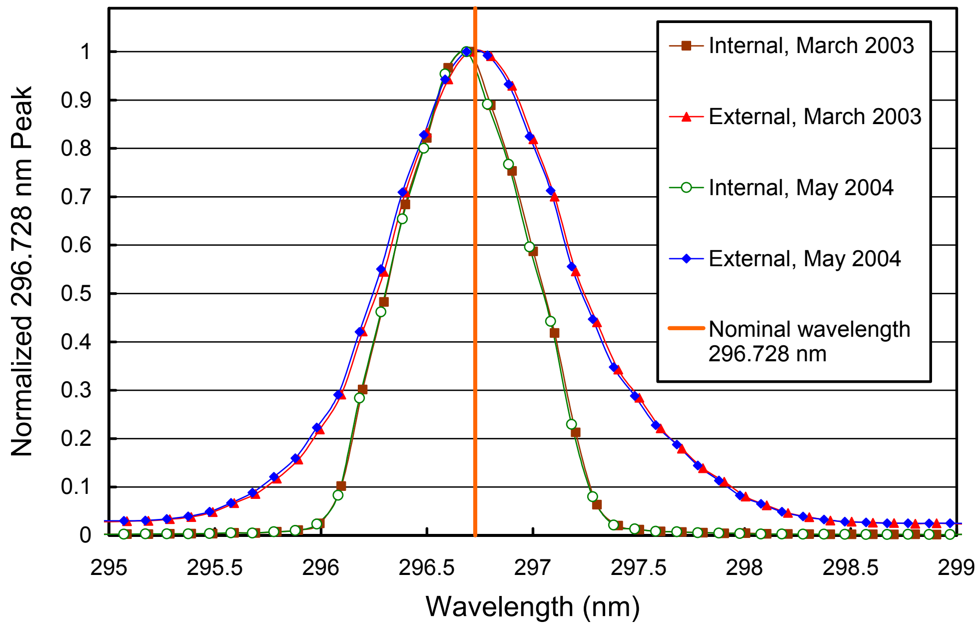

Figure 5.2.10. *The 296.73 mercury line as registered by the PMT from external and internal sources. The wavelength scale is the same as applied for solar measurements.*

5.2.4. Missing Data

A total of 21288 scans are part of the published Palmer Volume 13 data set. About 2% of solar scans were superseded by absolute, wavelength, and response scans. Since Palmer Station has almost 24 hours of sunlight per day in December, a loss of data scans cannot be avoided. About 1% of solar scans were lost due to technical problems. 32 scans were not recorded on 7/24/03 when the internal lamp was replaced. About 10 scans were lost during trouble shooting in response to increased signal noise observed in October 2003. 30 scans measured on 5/10/03 were overwritten when the GPS erroneously reset the system time by one day. 80 additional scans were lost throughout the season for various or unknown reasons.

5.3.5. GUV Data

The 2003/04 period was the second season at Palmer offering data from a multichannel filter instrument of type GUV-511. The GUV-511 instrument is installed next to the SUV-100 and provides measurements in four approximately 10 nm wide UV bands centered at 305, 320, 340, and 380 nm. A fifth channel measures photosynthetically active radiation (PAR). Data from the instrument are used to calculate total column ozone, spectral integrals, and dose rates for a large number of action spectra. These data products are made available in near real-time via the website http://www.biospherical.com/nsf/login/update.asp. Details about calibration and calculation of data products are at http://www.biospherical.com/nsf/presentations/SPIE_paper_5156-23_Bernhard.pdf . In addition to providing data via the Internet, the radiometer is also used to quality control SUV-100 measurements. For example, fluctuations in the ratio of measurements of the two instruments may indicate a problem with either of the two data sets, prompting for further examination.

After the 2003/04 season was finished, final GUV data were produced and are available on our ftp site.

Figure 5.2.11. shows a comparison of GUV-511 and SUV-100 erythemal irradiance based on the final data set. GUV and SUV data agree to within ±5% (±1σ) for solar zenith angles up to 80°.
The agreement for some data products (e.g. DNA damaging variation) may be worse that that for erythema due to principal limitations in calculating dose-rates from the five GUV-511 channels when the Sun is low and when the data product in question is heavily weighted toward wavelengths below 310 nm. We therefore advise data users to use SUV-100 rather than GUV-511 data when possible, in particular for low-Sun conditions.

Note that a new data set of SUV-100 data, named "Version 2" is currently being prepared (see http://www.biospherical.com/nsf/Version2/Version2.asp). Version 2 data are corrected for the cosine error of the SUV-100 spectroradiometer. Version 2 erythemal data are approximately 4-6% higher than Version 0 data discussed in this report. GUV measurements were calibrated both against Version 0 and Version 2 SUV-100 data, and both data sets were published. Preliminary GUV data made available via the website http://www.biospherical.com/nsf/login/update.asp are based on the calibration with the cosine corrected SUV-100 data set, and are therefore approximately 4-6% higher than the data plotted in Figure 5.2.11.

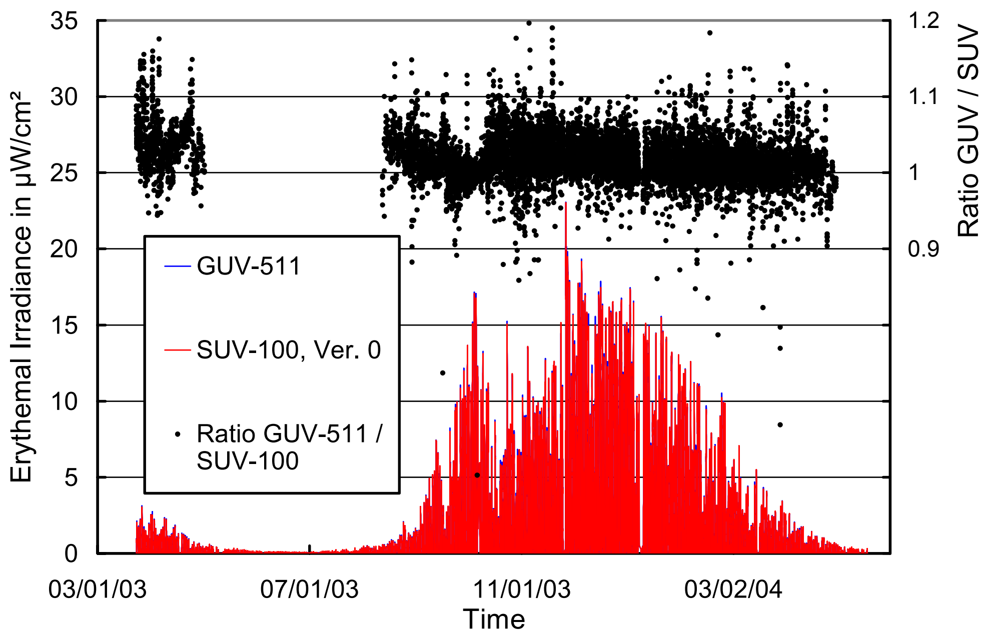

Figure 5.2.11. *Comparison of erythemal irradiance measured by the SUV-100 spectroradiometer and the GUV-511 radiometer. All data are based on "Version 0," see text. The ratio is restricted to measurements at SZAs smaller than 80°.*

Figure 5.2.12 shows a comparison of total ozone measurements from the GUV-511 and observations from the NASA/TOMS Earth Probe satellite. GUV-511 ozone values were calculated as described in http://www.biospherical.com/nsf/presentations/2003JD003450.pdf. Figure 5.2.12 indicates that TOMS and SUV-100 data are in excellent agreement.

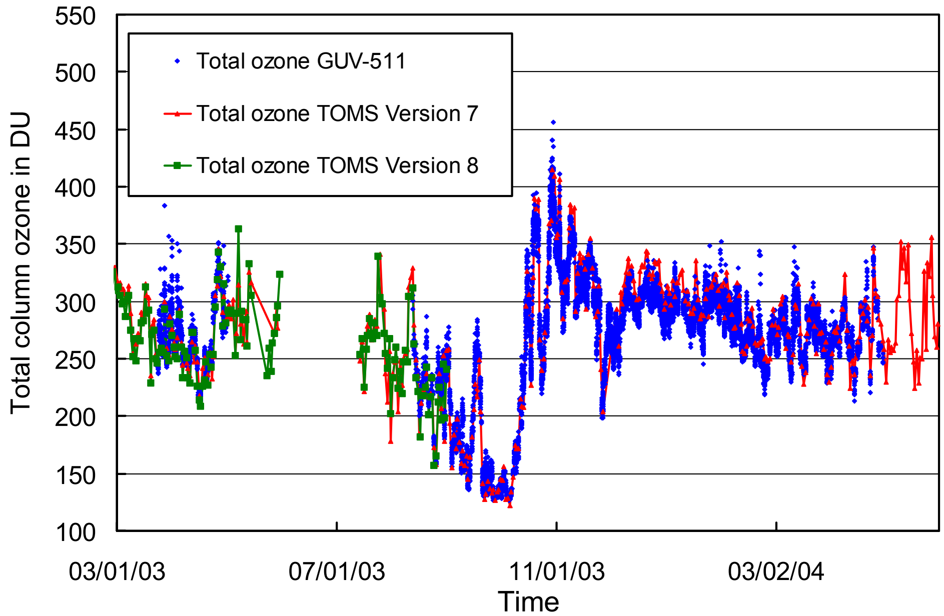

Figure 5.2.12. *Comparison of total column ozone measurements from GUV-511, and NASA/TOMS Earth Probe satellite.*