5.5. San Diego (8/22/03 – 10/4/04)

The 2003-2004 season at San Diego includes the period 8/22/03 – 10/4/04. In contrast to other network sites, San Diego serves also as a facility for operator training, test of new system components, and comparison of calibration standards. Scheduled maintenance is performed year-round and during operator training. The measurement of solar spectra is therefore more frequently interrupted than at other sites. The list below gives an overview of the most important non-standard activities during the San Diego Volume 13 season:

- **08/22/03:** Start of the season following operator training
- **09/16/03:** Spectroradiometer Control Panel testing
- **09/30/03 - 10/01/03:** Testing of Spectralink INT cards
- **10/15/03:** Testing of Spectralink INT cards
- **10/18/03:** Testing of Spectralink INT cards
- **11/12/03 – 11/21/03:** Training of field engineer
- **12/09/03:** Stray light characterization
- **01/29/04:** Replacement fuse of PMT cooler
- **02/27/04:** Time adjusted by 30 seconds
- **03/22/04:** Application of Operating System upgrades and installation of Eppley PSP pyranometer
- **03/23/04 – 03/24/04:** Repair of building roof; testing GPS unit
- **04/05/04:** Computer power cord found disconnected
- **4/26/04 – 4/28/04:** Repainting of instrument room ("penthouse")
- **05/18/04 – 05/24/04:** Comparison with SUV-150B spectroradiometer
- **06/03/04:** Test, removal, and reinstallation of PMT/PMT cooler unit
- **07/14/04:** Test of external mercury lamps
- **9/21/04 – 9/23/04:** Installation of Barrow system control computer for troubleshooting
- **09/23/04:** Repair of cable between computer and Spectralink
- **10/04/04:** End of season and start of operator training.

On 10/25/04, a devastating wildfire broke out in San Diego county. While the instrument was not affected, measurements on 10/26/03 and 10/27/03 were extraordinarily low due to smoke. See Section 7.5 for details.

With exception of some problems described below, the system operated normally during the Volume 13 period. Approximately 97% of the scheduled data scans are part of the published dataset. Only a very small fraction of all solar scans was lost due to technical problems. The majority of the missing scans were superceded by operator training, upgrades, tests, instrument calibration, and maintenance.

Like Volume 12, Volume 13 also includes data from a GUV-511 moderate-bandwidth filter radiometer (see Section 2). These data complement SUV-100 measurements and are also used for quality control. A comparison of GUV-511 and SUV-100 data is provided in Section 5.5.5.

5.5.1. Irradiance Calibration

The calibration of Volume 13 solar data was mostly based on lamp 200W028. The lamp was frequently compared with the traveling standards M-764 and also with the alternative traveling standard 200W017. All lamps had been calibrated by Optronic Laboratories in March 2001. The calibration of M-764 was further confirmed during audits by NOAA's Central UV Calibration Facility (CUCF).

Figure 5.5.1 shows a comparison of 200W028 and 200W017 with M-764 performed on several days throughout the season. Lamps 200W028 and M-764 agree to within ±1.5%. Lamp 200W017 deviates from M-764 by 3% in the UV. Comparisons of lamp 200W017 with further lamps performed at other sites indicated a similar bias. Scans of lamp 200W017 were therefore not used for calibrations of the San Diego instrument during the Volume 13 season.

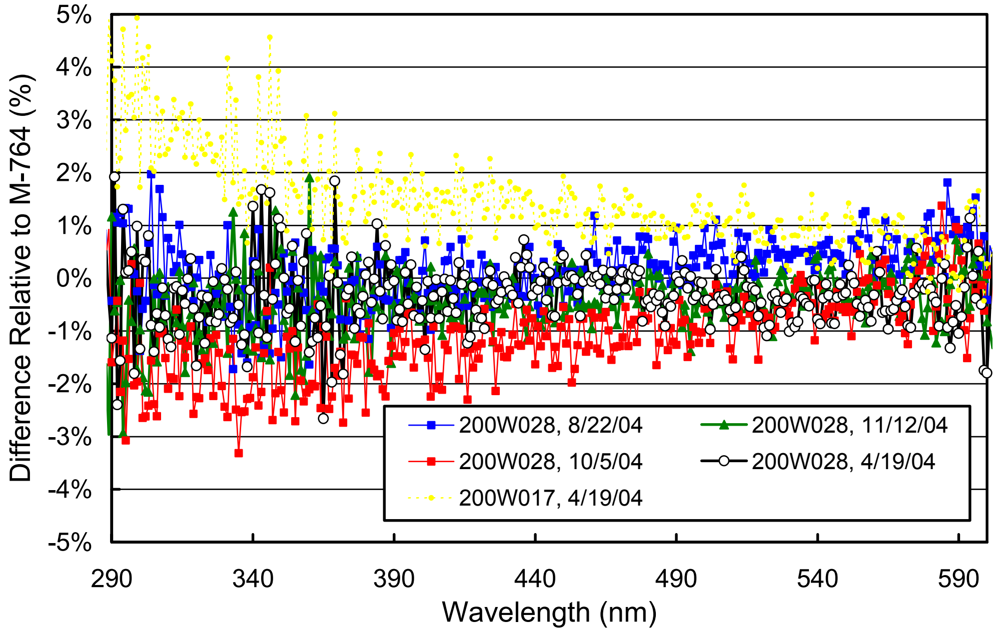

Figure 5.5.1. *Comparison of 200W028 and 200W017 with the traveling standard M-764.*

5.5.2. 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 lamp. 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 this lamp has drifted by more than 2%.

Figure 5.5.2 shows TSI measurements and PMT currents at 300 and 400 nm during response scans. The season is considered in two parts, labeled Part 1 and Part 2. Training and associated system service took place between both parts. TSI and PMT data were normalized to the average value of the entire season, which explains the step in PMT currents between the two parts. Measurements of the TSI were only little affected by the instrument maintenance and show a downward drift of approximately 4% during the Volume 13 period, indicating that the internal lamp became 4% darker. Small steps in the TSI time series of approximately 1% occurred on 11/22/03 and 1/15/04, when the value of the shunt, which is used to control the lamp current, was adjusted. PMT measurements on 1/29/04 are 5% low. This temporary drop was caused by a failure of the fuse of the PMT cooler power supply. Solar data between 1/28/04 and 1/30/04 have consequently an increased uncertainty. However, a comparison between SUV-100 and GUV-511 data (Section 5.5.5) did not indicate that SUV-100 data are anomalously low or high during the affected period. On 6/3/04, PMT and PMT cooler housing were temporarily removed to test a new PMT cooler for installation at Palmer Station. This introduced a 2% change into PMT current time series.

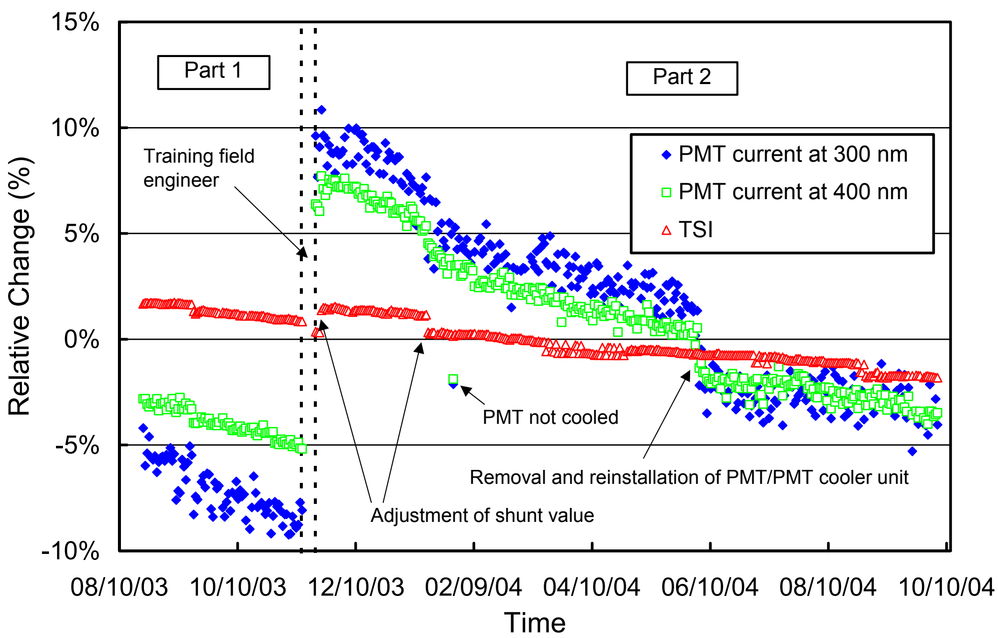

Figure 5.5.2. *Time-series of PMT current at 300 and 400 nm, and TSI signal calculated from measurements of the internal irradiance reference lamp during the San Diego 2003-2004 season. The data is normalized to the average value of the entire period.*

Figure 5.5.3 shows the change of the spectral irradiance assigned to the internal reference lamp. There is a large change in the assigned irradiance between Period P2 and P3 owing to field engineer training and instrument service. System sensitivity drifts between Periods P3 and P6 were below 5%. Calibration periods are summarized in Table 5.5.1.

The season opening calibrations, which were performed on 8/16/02, deviate by 3-5% from results of the next calibration on 8/30/02. This change is likely caused by settling of the system after service. The calibration of solar scans during the last two weeks in August 2002 is affected by an additional 4% uncertainty as the temporal behavior of the settling process could not be resolved.

Table 5.5.1: Assignment of calibration periods.

Period			Number of absolute scans	Remarks
Label	Start	End		
P1	08/22/03	10/09/03	5	
P2	10/10/03	11/16/03	4	Field engineer / system service after this period
P3	11/17/03	12/11/03	5	
P4	12/12/03	3/6/04	6	
P5	03/07/04	05/27/04	5	
P6	05/28/04	10/4/04	12	

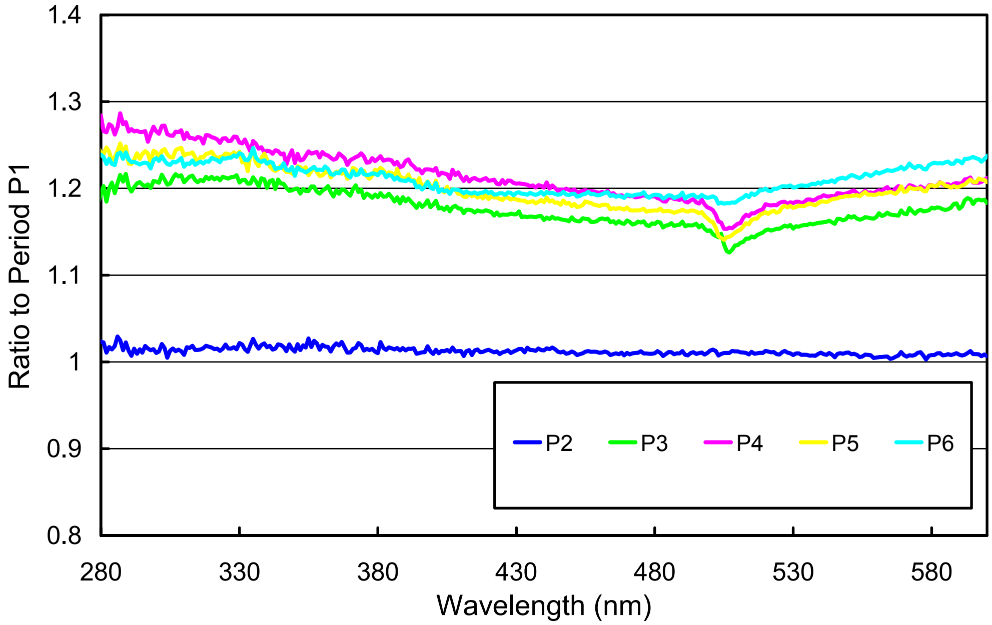

Figure 5.5.3. *Ratios of irradiance assigned to the internal reference lamp. See Table 5.5.1 for period assignment.*

Figure 5.5.4 shows the relative standard deviation of the spectra that contribute to the irradiance spectra assigned to the internal lamp in each period. The plot is useful for estimating the variability of calibrations in a given period. Calibrations were generally consistent to within 1.5% (1σ) for wavelength above 300 nm. At shorter wavelengths, the calibrations are affected by noise resulting in a somewhat larger variability.

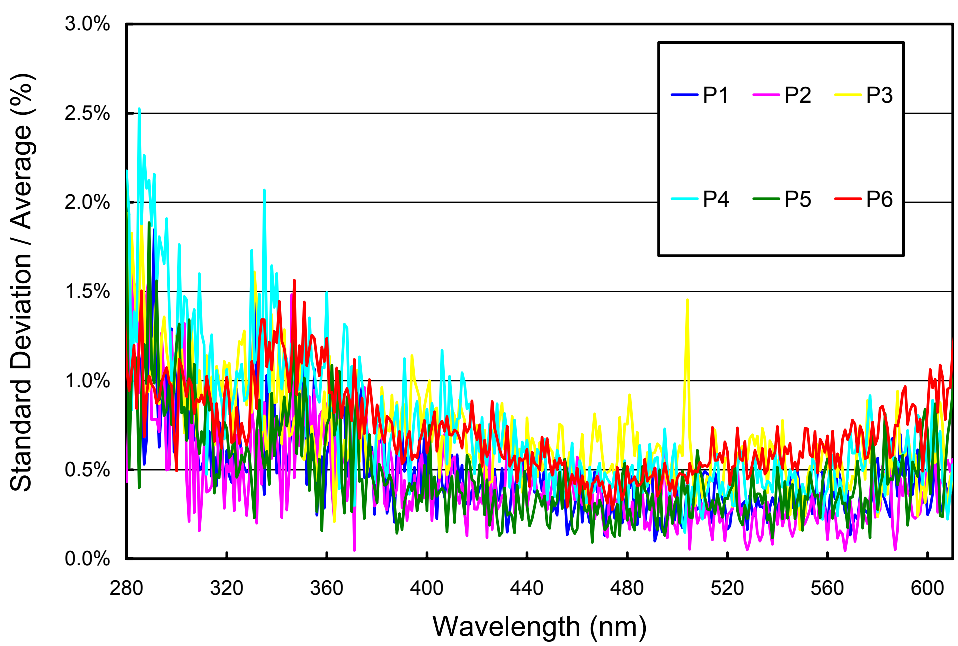

Figure 5.5.4. *Ratio of standard deviation and average calculated from the absolute calibration scans that were used to establish the calibration of the San Diego spectroradiometer for the 2003-2004 season.*

5.5.3. 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 5.5.5 shows the differences in the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 454 scans were evaluated. For 95% of the days, the change in offset was smaller than ±0.025 nm; for 97% of all days shifts were below 0.055 nm. Twelve scans showed a change larger than ±0.1 nm. These changes are mostly caused by system maintenance. The wavelength calibration was adjusted accordingly.

After 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 new Fraunhofer correlation method developed for Version 2 NSF network data (*Bernhard et al.*, 2004). In contrast to the previously used algorithm (Section 4.2), shifts for the whole spectral range are determined and results from internal wavelength scans are not required. Seven different functions were applied, which vary by approximately ±0.5 nm (Figure 5.5.6).

After the data was wavelength corrected using the shift function described above, the wavelength accuracy was confirmed with the Fraunhofer method. The results are shown in Figure 5.5.7 for four UV wavelengths, evaluated for all noontime scans measured during the season. The residual shifts are typically smaller than ±0.05 nm. The actual wavelength uncertainty may be larger due to wavelength fluctuations of about ±0.02 nm during the day. When clouds move in front of the Sun spectra will get distorted, which may confuse the algorithm. This, and not real wavelength shifts, are the likely reason for the few outliers seen in Figure 5.5.6.

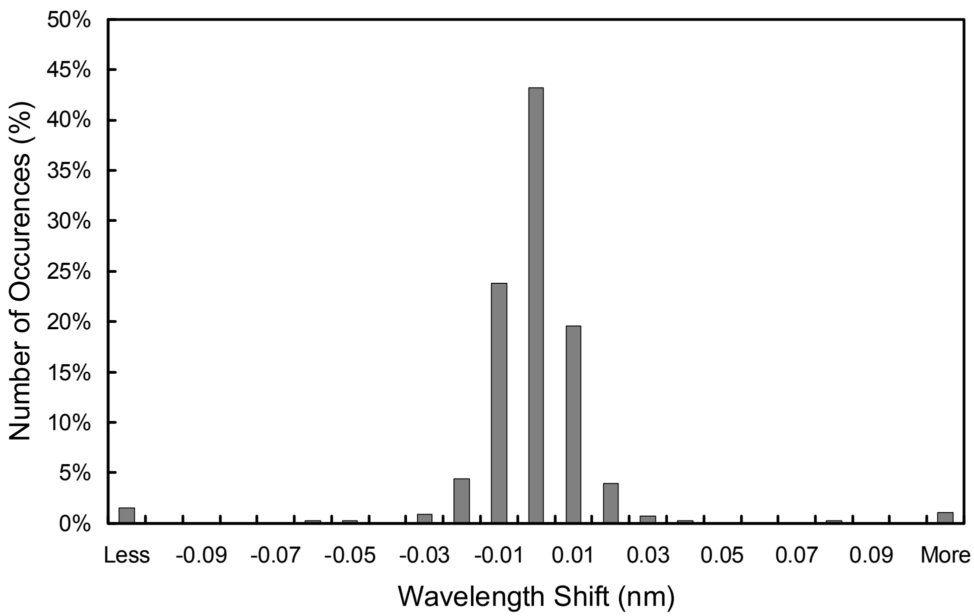

Figure 5.5.5. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. The 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more" means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

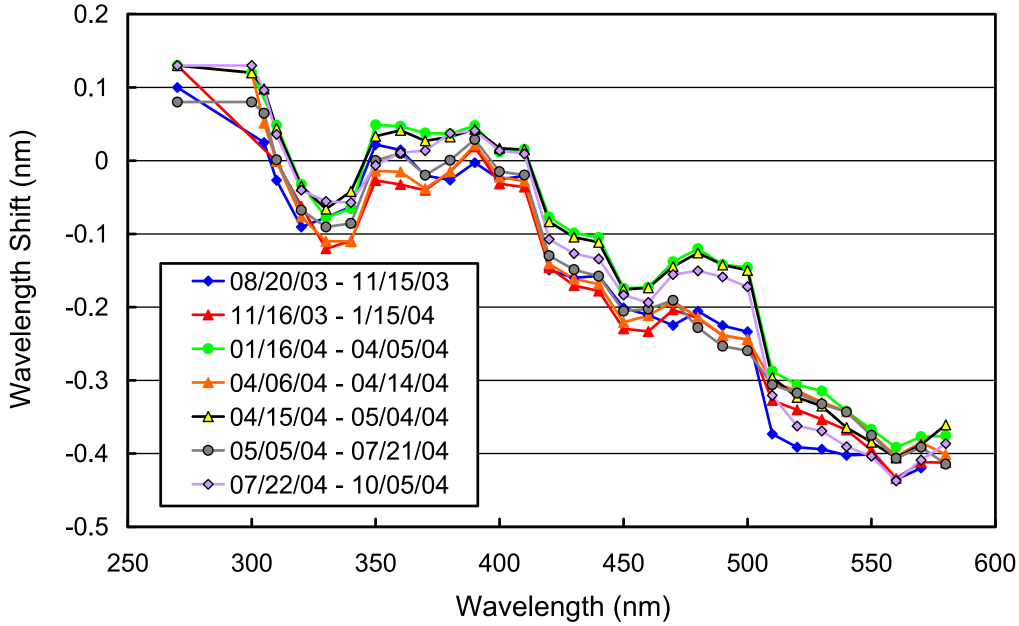

Figure 5.5.6. *Monochromator non-linearity correction functions for the San Diego 2003-2004 season.*

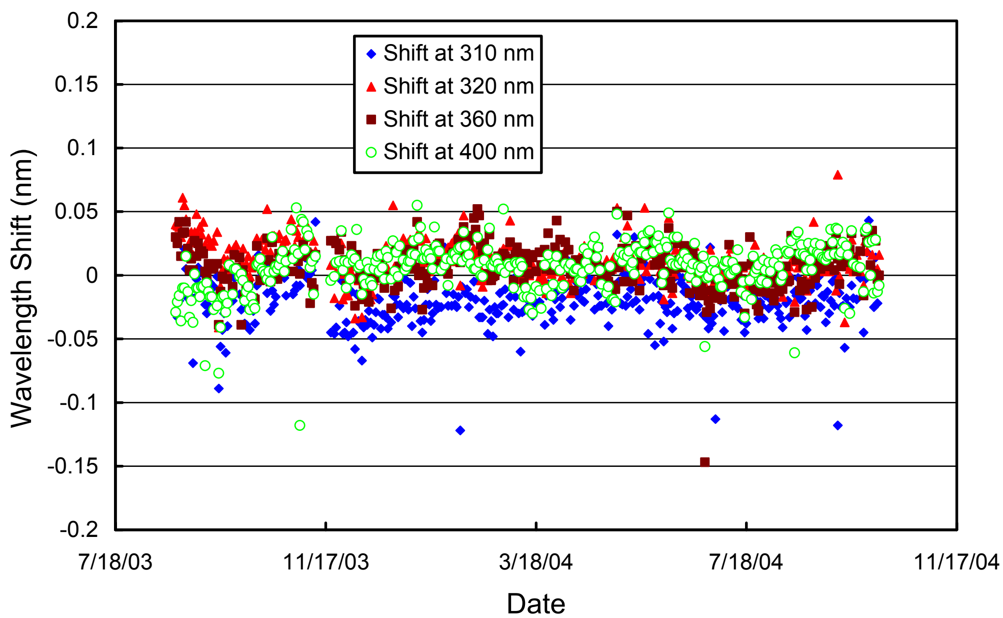

Figure 5.5.7. *Check of the wavelength accuracy of final data at four wavelengths by means of Fraunhofer-line correlation. The noontime measurements have been evaluated for each day of the season.*

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 5.5.8 shows internal and external mercury scans measured after the field engineer training in November 2003 and at the end of the Volume 13 period in October 2004. Line shapes recorded during both events are similar. The bandwidth of external scans was 1.05 nm; that was internal scans was 0.91 nm. External scans have the same light path as solar measurement. The shift between the center positions of both scan types is 0.12 nm. This shift is caused by the different light paths for both scan types; see Section 4.1.4 for details.

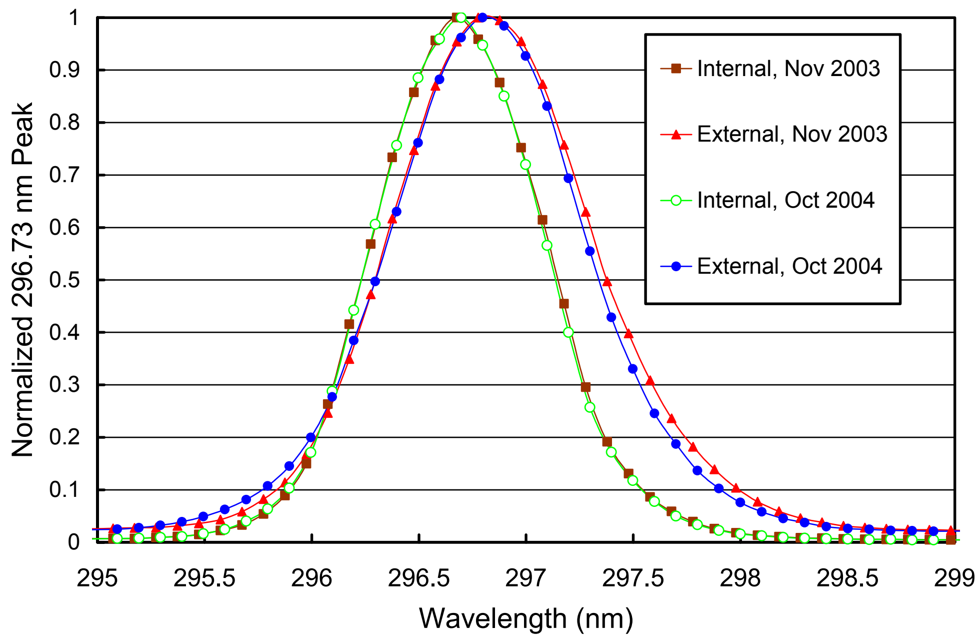

Figure 5.5.8. *The 296.73 mercury line as registered by the PMT from external and internal sources.*

5.5.4. Missing Data

A total of 19618 scans are part of the published San Diego Volume 13 dataset. These are 97% of all scans scheduled between 8/22/03 and 10/4/04. Approximately 1.4% of all scans were superceded by calibrations performed throughout the season. Mid-season operator training in November 2003 lead to a loss of 334 scans. Additional reasons for missing solar data are technical problems (0.4 %), repair and painting of the building (0.5%), and additional system tests and upgrades. Table 5.5.2 describes the gaps in the published solar data in more detail.

Table 5.5.2 Missing scans San Diego Volume 13 (gaps due to calibration activities are not included).

Time Period	Scans missing	Reason
09/16/03	5	Application of Operating System upgrades
09/30/03 – 10/01/03	28	Test Spektralink INT cards
10/01/03	22	Test Spektralink INT cards
10/18/03	4	Test Spektralink INT cards
10/21/03 – 10/22/03	5	Testing of software
10/27/03	15	Missing for unknown reasons
11/12/03 – 11/22/03	334	Field engineer training
12/07/03	4	Missing for unknown reasons
12/09/03	4	Stray light characterization
01/21/04	3	Test GPS unit
01/29/04	6	Replacement fuse PMT cooler
02/28/04	5	Unspecified system tests
03/22/04	4	Application of Operating System upgrades
03/23/04 – 03/24/04	14	Repair of roof
04/05/04	12	Computer power cord disconnected for unknown reasons
04/26/04 – 04/28/04	94	Repair and painting of roof box
06/03/04	11	Test, removal and reinstallation of PMT/PMT cooler unit
07/14/04	9	Test of mercury lamps
09/21/04 – 09/23/04	91	Repair and test of system control computer of Barrow installation
09/23/04	2	Shutter actuation defective

5.5.5. GUV Data

During 2001, we started deploying Biospherical Instruments GUV-511 moderate-bandwidth filter radiometer at network sites in close proximity to the collector of the SUV-100. The GUV-511 instrument provides measurements in four approximately 10 nm wide UV bands centered at 305, 320, 340, and 380 nm, as well as photosynthetically active radiation (PAR). From data recorded at these wavelengths, total column ozone, spectral integrals, and dose rates for a large number of action spectra is calculated and 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.

Figure 5.5.9 shows a comparison of GUV-511 and SUV-100 erythemal irradiance for solar zenith angles smaller than 80°. The average ratio of both data sets is 1.010. No GUV-511 data are available for the period 3/30/04 – 4/17/04. Some small steps in the ratio coincide with calibration changes of the SUV-100. The agreement for some data products (e.g. DNA damaging variation) may be worse than that for erythema due to principal limitations in calculating dose-rates from the four 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 in preparation (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 6% higher than the Version 0 data that are discussed in this report. GUV measurements were calibrated both against cosine error corrected and uncorrected 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 6% higher than data plotted in Figure 5.5.9.

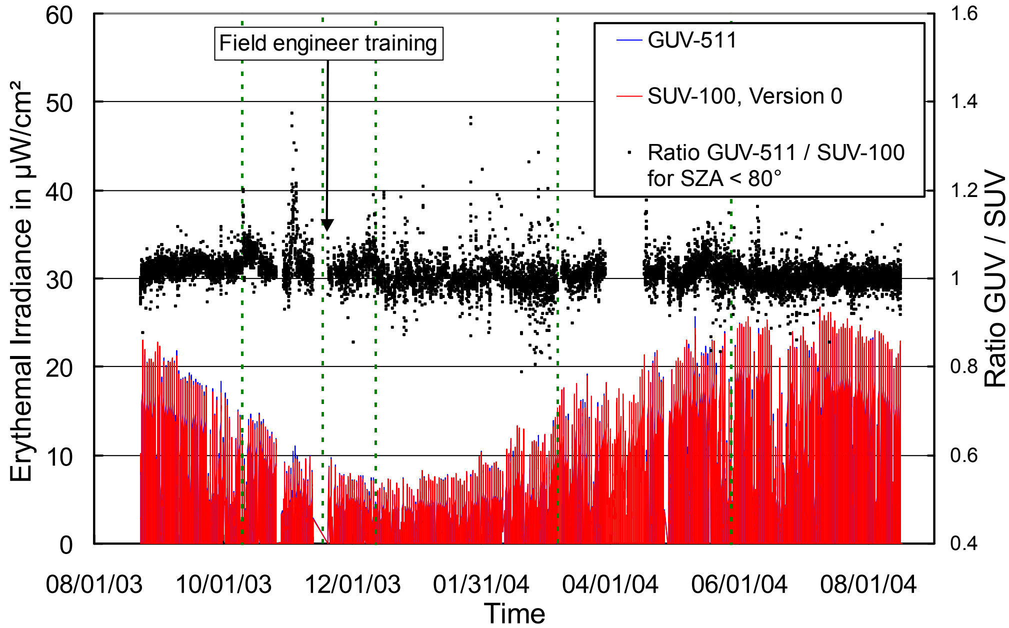

Figure 5.5.9. *Comparison of erythemal irradiance measured by the SUV-100 spectroradiometer and the GUV-511 radiometer. All data is based on "Version 0" (cosine-error uncorrected) data. Broken lines indicate days when the SUV-100 calibration was changed.*

Figure 5.5.10 shows a comparison of total ozone measurements from the GUV-511 and Version 8 data from the NASA/TOMS instrument on the Earth Probe satellite. GUV-511 ozone values were calculated as described in http://www.biospherical.com/nsf/presentations/SPIE_paper_5156-23_Bernhard.pdf. TOMS ozone values are on average 2% lower than GUV-511 data.

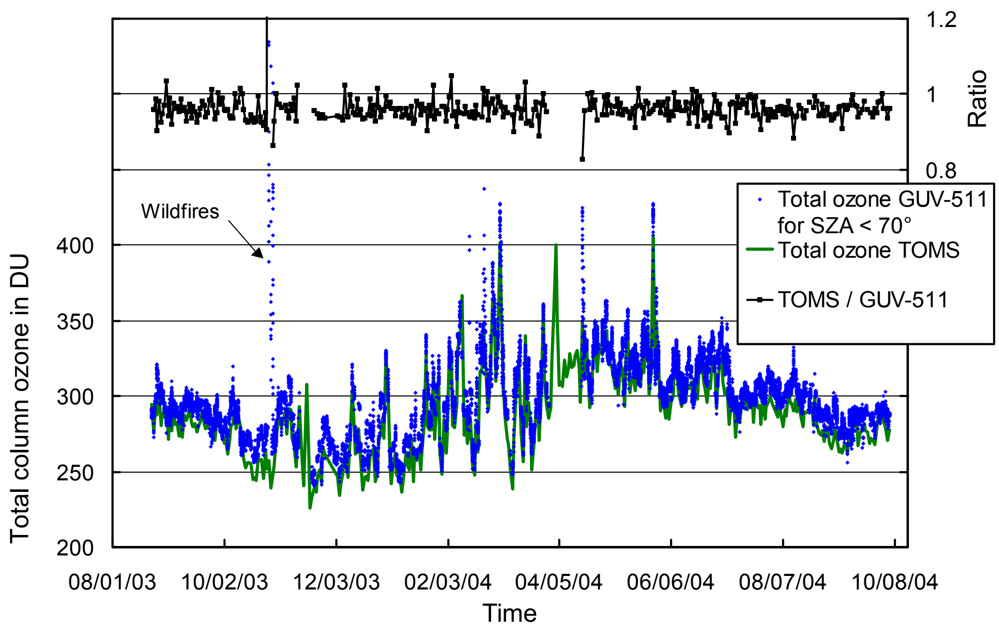

Figure 5.5.10. *Comparison of total column ozone measurements from GUV-511 and NASA/TOMS Earth Probe satellite. GUV-511 measurements are plotted in 15 minute intervals. For calculating the ratio of both data sets only GUV-511 measurements concurrent with the TOMS overpass data were evaluated.*