5.2. Palmer Station (6/5/04 – 4/13/06)

This sections describes quality control of solar data recorded at Palmer Station between 6/5/04 and 4/13/06. There was no site visit in 2005. Solar data recorded between 6/5/04 and 6/21/05 were assigned to Volume 14; data covering the period 6/22/05 – 4/13/06 are part of Volume 15. Opening and closing calibrations of the 2-year period described in this section were performed on 6/4/04 – 6/5/04 and 4/14/06, respectively. After performing the season closing calibrations, the system was relocated to the new "Terra Lab" building (Section 3.2).

Measurements or the reporting period were affected by several issues, which are described below. Technical problems were addressed during data processing and their impact on the quality of published SUV-100 data is typically small. Periods with increased uncertainty are indicated.

- **Drifts of internal lamp and system responsivity**
  The system was affected by two sources of instability during the reporting period. First, the internal lamp became unstable in November 2004 and was eventually replaced. Second, the sensitivity of the instrument abruptly changed by several percent on seven occasions. We were not able to determine the reason of these step-changes with certainty, but tests during the site visit in 2006 indicated that the monochromator was the likely cause of the problem. The reporting period was divided into 28 calibration periods in response to these changes. Comparisons with the GUV-511 radiometer indicate that drifts in SUV-100 data were successfully removed.

- **Inference with Terra Lab building**
  "Terra Lab" was built in 2005 next to the annex of the T-5 building where the SUV-100 has been located during the last years. Construction started to interfere with UV measurements on April 13, 2005. External lights used for construction may have affected measurements in May and June 2005. After May 1, one side wall of the new facility obstructed the southerly horizon seen from the instrument's collector. A survey of the building's outline is available in Section 3.2. Terra Lab was in view of the collector at azimuth angels between 143° and 198° (South equals 180°). The blockage was highest at 220°. At this azimuth angle, the building extended 26° over the horizon. Shading from the building reduced diffuse irradiance from the sky by 5.2% according to our calculations. These calculations assume that the building does not reflect radiation and that sky radiance is isotropic. The latter is a good approximation in the UV-B, and under overcast skies. Between May and September 2005, the solar zenith angle was larger than 90° for the range of azimuth angles blocked by the building. Only the diffuse irradiance was therefore affected by the building during these months. Depending on time of day, the direct Sun may have been blocked during clear sky periods between September 2005 and April 2006. No corrections for shading were applied. We note that shading was corrected for "Version 2" data, available at www.biospherical.com/nsf/Version2/.

- **Time errors**
  The GPS unit erroneously changed the computer time backward by one day on 10/22/04 and 11/21/05. Data from 10/22/04 were lost. SUV data from the event in 2005 could be salvaged because measurements had been archived offsite before they were overwritten by the system control software. GUV data from 11/21/05 2:00 – 11/21/05 17:00 are not available.

The Volume 14 and 15 seasons resulted in a total of 36272 solar scans. Less than 3% of all scans were lost due to technical problems.

5.2.1. Irradiance Calibration

The site irradiance standards for 2004-2006 were the lamps 200W007, M-765, and M-700. Lamp M-764 was used as the traveling standard at the beginning of the reporting period. This lamp has drifted by about 2% between 2004 and 2006 and there is some indication that its calibration during the Palmer site visit in June 2004 was already affected by the drift. The traveling standard at the end of the period was lamp 200W017. Lamps M-764 and 200W017 were calibrated by Optronic Laboratories in March 2001, but lamp 200W017 was used less frequently.

Lamp 200W017 was compared with the BSI long-term standards M-763 and 200W022 on 1/6/06 (before the 2006 Palmer site visit) and on 6/1/06 (after the site visit). The calibration of lamp 200W017 agreed with the calibration of the two long-term standards to within ±1% on both occasions, independent of wavelength. Lamps M-763 and 200W022 have Optronic Laboratories calibrations from March 2001. The two lamps are used very sparingly and are kept at BSI at all times. There is no indication that their calibration has drifted. We conclude from the comparison that also the calibration of lamp 200W017 has not drifted since its original calibration in March 2001.

The site standard 200W007 has an irradiance calibration from Optronic Laboratories from November 1996. Lamp M-765 was originally calibrated by Optronic Laboratories in October 1992 and has been recalibrated in 2000 by comparison 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 calibration of the three site standards was not changed since the year 2000 and solar data of Volumes 10 – 13 have been calibrated with the same set of calibration values.

Figure 5.2.1 shows the comparison of the three site standards with traveling standard 200W017 performed on 4/14/06. The site standards agree with each other to within ±1%, but there is a systematic bias to the calibration of lamp 200W017 of about 2.5% at 300 nm, 1% at 360 nm, and 0.5% in the visible. Since we have confidence in the calibration of 200W017 and since the calibrations of the site standards was established more than 6 years ago, we decided to recalibrate all three site standards. This recalibration was performed by comparison with lamp 200W017 using absolutes scans performed on 4/14/06 ("closing scans" Volume 15) and 4/28/06 ("opening scans" Volume 16). Figure 5.2.2. shows a comparison of the recalibrated site standards with lamp 200W017. (The figure is based on the same raw data as Figure 5.2.1., but uses the updated calibration information).

The site standards 200W007, M-765, and M-700 were compared eight times with each other between 7/2/04 and 3/24/06. The lamps' calibrations agreed to within ±1% on all occasions, indicating good stability during the reporting period. As an example, Figure 5.2.3 presents a comparison of the three lamps performed on 9/22/04. Season "opening" calibrations were performed on 6/4/04 and 6/5/04, shortly after installing a new PMT housing. Data indicate that the system had not fully stabilized at the time when the scans were executed. No valuable conclusions can therefore be drawn from the opening calibrations and no results are presented here.

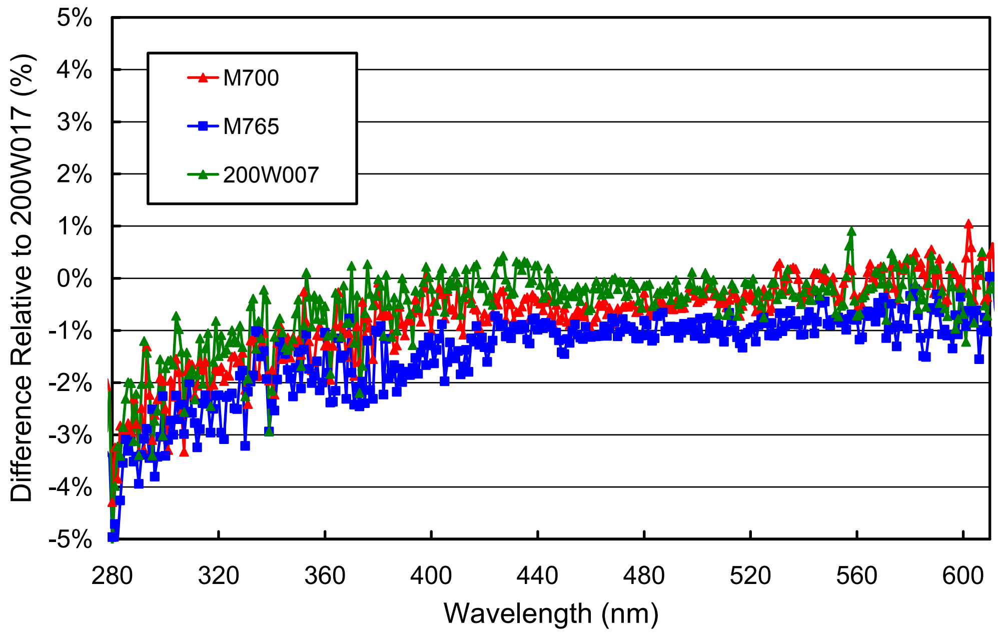

Figure 5.2.1. *Comparison of Palmer lamps 200W007, M-700, and M-765 with the BSI traveling standard 200W017 on 4/14/06. Results are based on the calibrations of lamps 200W007, M-700, and M-765 used for Volumes 10 – 13.*

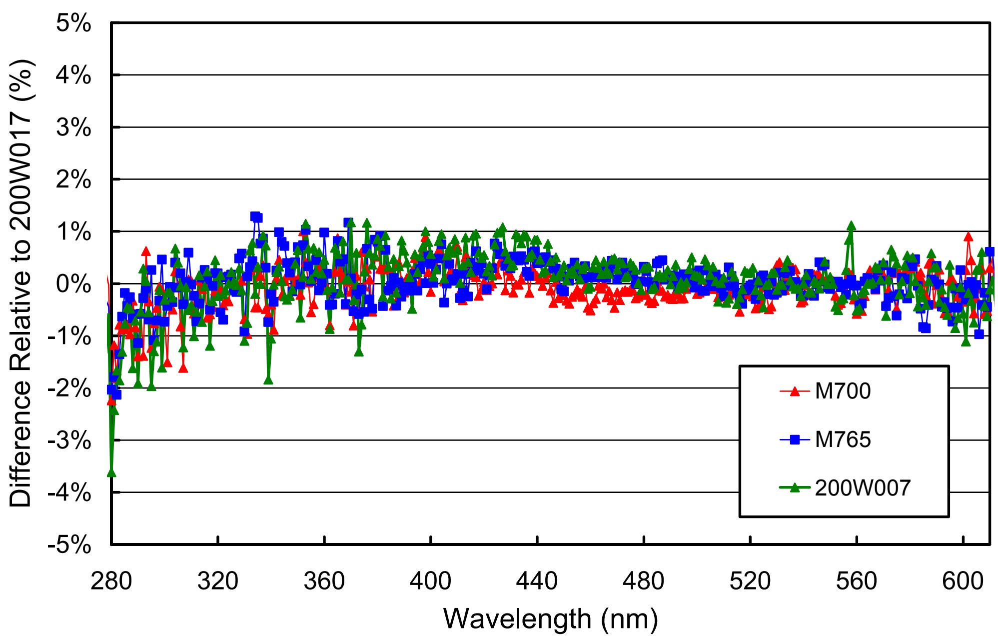

Figure 5.2.2. *Comparison of Palmer lamps 200W007, M-700, and M-765 with the BSI traveling standard 200W017 on 4/14/06. Results are based on the updated calibration functions of lamps 200W007, M-700, and M-765 that were established following the 2006 site visit. These calibration functions were used for processing of solar data of the reporting period.*

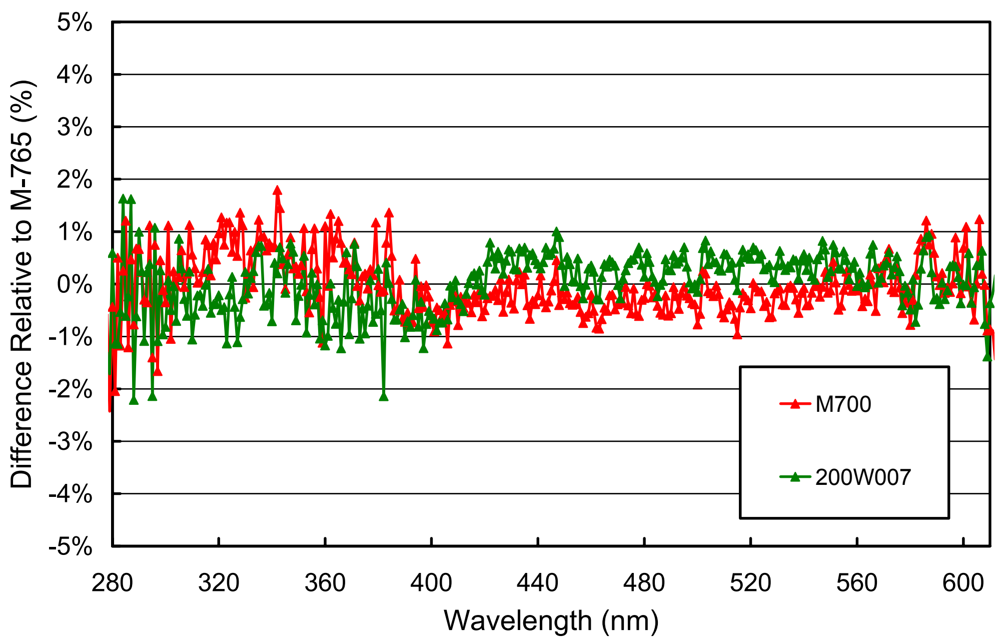

Figure 5.2.3. *Comparison of Palmer lamps 200W007, M-700, and M-765 on 9/22/04. Results are based on the updated calibration functions of the three lamps.*

5.2.2. Instrument Stability

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. By logging the PMT currents at several wavelengths during response scans, changes in the instrument responsivity can be detected.

The system was affected by two sources of instability during the reporting period. First, the internal lamp became unstable on 11/16/04 and exhibited several abrupt changes by up to 5% between November 2004 and May 2005. On 5/15/05 the lamp became darker by 8%. The problem worsened in August 2005, and the lamp was eventually replaced on 9/2/05. The new lamp was very stable (drift by less than 0.4% per month). Second, the sensitivity of the instrument abruptly changed by several percent on seven occasions. Affected days and observed changes are: 7/1/04 (+9%), 7/20/04 (-5%), 6/6/05 (+11%), 6/16/05 (+4%), 7/12/05 (+10%), 7/14/05 (-5%), and 10/10/05 (-5%). We were not able to determine the reason of the step-changes while the system was installed at Palmer. Tests during the site visit in 2006 suggested that the monochromator was the likely cause of the problem. The monochromator was consequently replaced. The system was typically stable to within ±2% between days when step-changes occurred. One exception is the mid-winter period 6/6/04-6/30/06, when the sensitivity gradually increased by 5.5%.

The reporting period was divided into 28 periods in order to correct for step changes caused by instabilities of the internal lamp and the monochromator throughput. A different irradiance spectrum was applied to the internal reference lamp in each of the 28 periods. Calibration periods and their drift-related uncertainties are summarized in Table 5.2.1. No absolute scans were performed in periods P16, P19, and P22. Further analysis indicated that the responsibilities of these periods were comparable to those of periods P18, P21, and P24, respectively.

The calibration of some periods is based on one absolute scan only. Calibration functions for other periods are based on up to 17 absolute scans, which were averaged according to the procedure described in Section 4.2.1.2. The standard deviations of individual spectra contributing to the average spectrum of a given period were also determined. Ratios of the “standard deviation spectrum” and the “average spectrum” were calculated for each period and are plotted in the Figure 5.2.4. These “relative standard deviation spectra” are a useful tool to assess the variability of calibrations within a given calibration period. The relative standard deviation is usually less than 1.5% for wavelengths larger than 300 nm, indicating good consistency of absolute scans performed within each period.

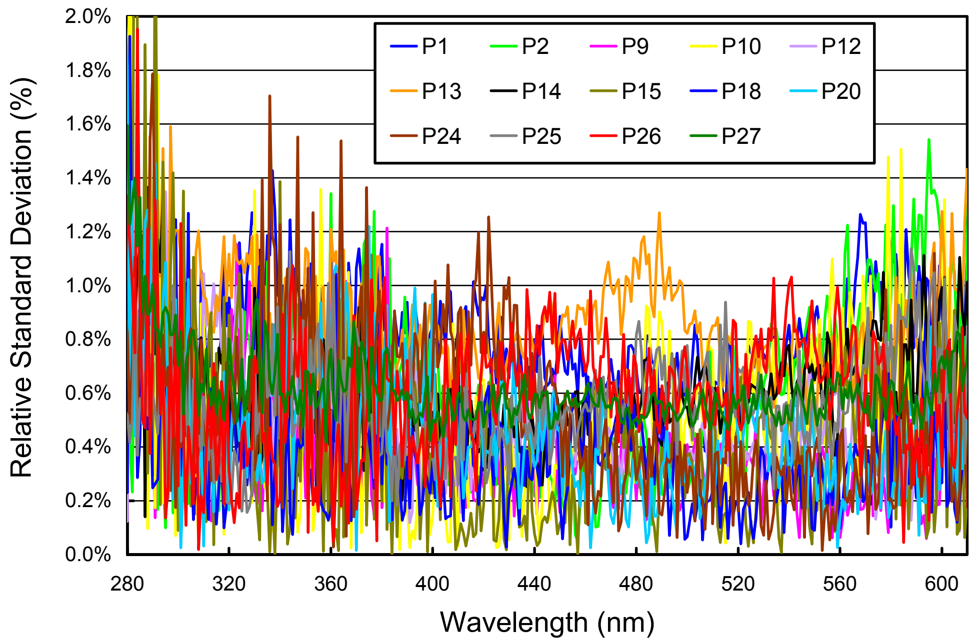

Figure 5.2.4. *Relative standard deviation spectra for periods with more than one absolute scan.*

To test the accuracy of final SUV-100 data, measurements at 340 nm were compared with measurements of the 340 nm channel of the collocated GUV-511 radiometer (see also Section 5.2.5). For this comparison, SUV-100 spectra were weighted with the response function of the GUV-511 instrument according to the procedure described in Section 4.3.1. The same calibration factor was applied to GUV measurements of the entire period. Figures 5.2.5a - 5.2.5d show the ratio of GUV to SUV measurements for four sub-periods. These ratios typically very between 0.95 and 1.05; the standard deviation is 0.04. Ratios are usually stable to within ±3% within a certain calibration period, with the exception of periods P1, P19, and P21. Period P1 encompasses June 2004 when the Sun was less than 3° above the horizon. Period P19 is only two days long, and the calibration for this period was adopted from Period P21. The systems responsivity during Period P21 has changed by about 5%, and the uncertainty of this period is increased.

Table 5.2.1: 1-σ standard uncertainty of system calibration caused by drifts of the internal lamp and monochromator throughput.

Period		Number of absolute scans	Uncertainty	Remarks
Label	Period range		in %	
P1	06/05/04-06/30/04	6	3	
P2	07/01/04-07/12/04	3	2	
P3	07/13/04-07/20/04	1	1	
P4	07/21/04-08/03/04	1	2	
P5	08/04/04-08/08/04	1	1	
P6	08/09/04-08/24/04	1	2	
P7	08/25/04-08/29/04	1	1	
P8	08/30/04-09/16/04	1	1	
P9	09/17/04-09/30/04	3	1	
P10	10/01/04-10/31/05	2	1	
P11	11/01/04-11/18/04	1	1	
P12	11/19/04-12/19/04	5	2	
P12b	12/20/04-12/27/04	0	4	Interpolated from P12 and P13
P13	12/28/04-02/27/05	5	3	
P14	02/28/05-05/14/05	7	2	
P15	05/15/05-06/06/05	2	2	
P16	06/07/05-06/15/05	0	3	Identical to P18
P17	06/16/05-06/30/05	1	1	
P18	07/01/05-07/12/05	3	1	
P19	07/13/05-07/14/05	0	4	Identical to P21
P20	07/15/05-08/15/05	3	1	
P21	08/16/05-09/02/05	2	3	
P22	09/03/05-09/06/05	0	3	Identical to P24, new internal lamp
P23	09/07/05-09/09/05	1	1	
P24	09/10/05-10/10/05	3	2	
P25	10/11/05-12/09/05	5	2	
P26	12/10/05-12/26/05	3	1	
P27	12/27/05-04/15/06	17	2	

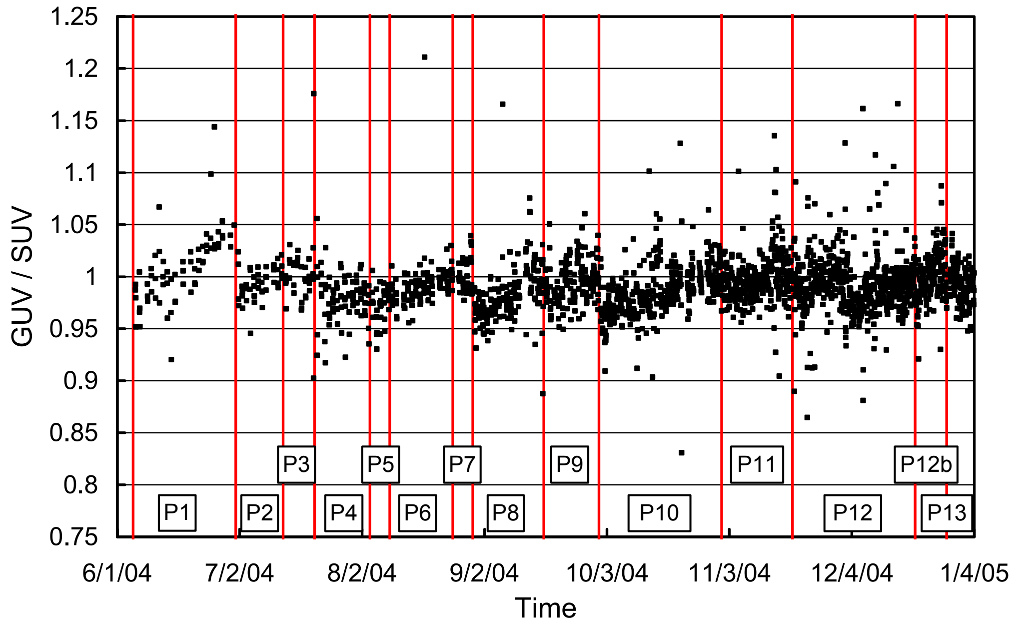

Figure 5.2.5a. *Ratio of GUV-511 and SUV-100 measurements from the year 2004. Red lines indicate limits of calibration periods P1 - P13.*

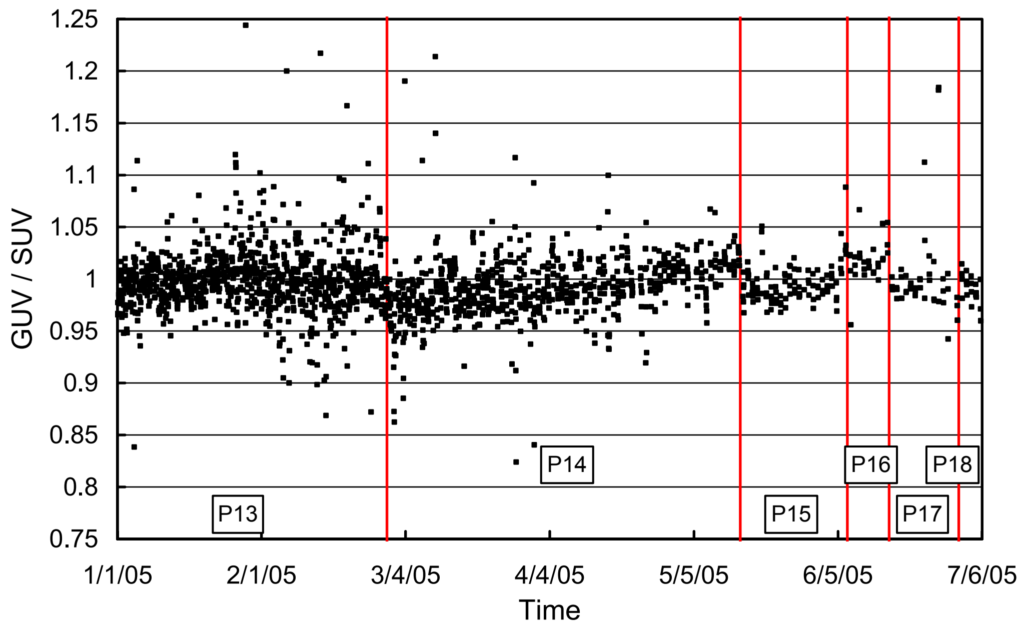

Figure 5.2.5b. *Ratio of GUV-511 and SUV-100 measurements from the first half of 2005.*

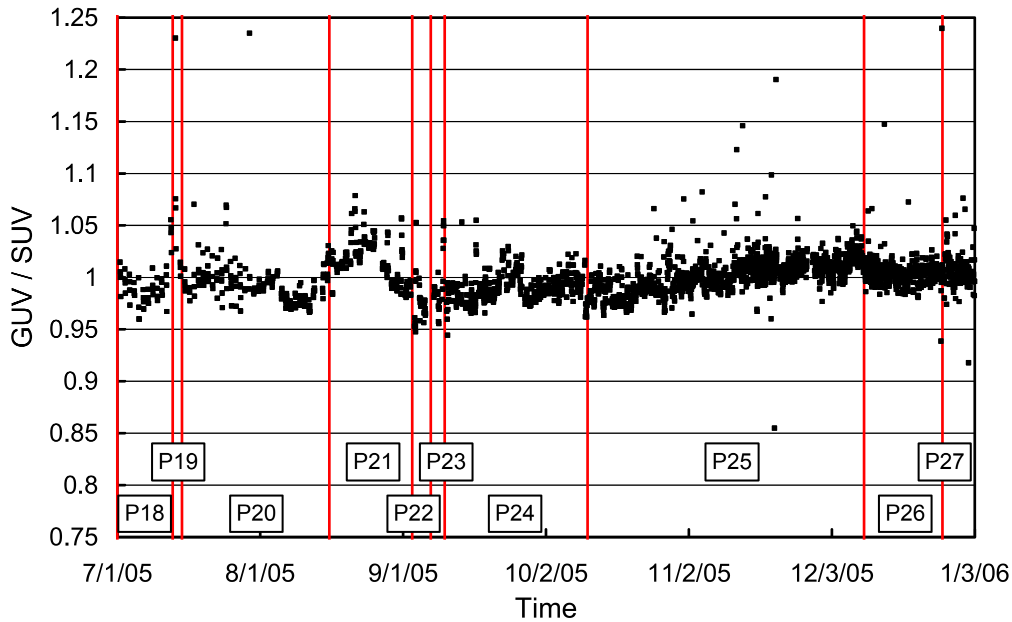

Figure 5.2.5c. *Ratio of GUV-511 and SUV-100 measurements from the second half of 2005.*

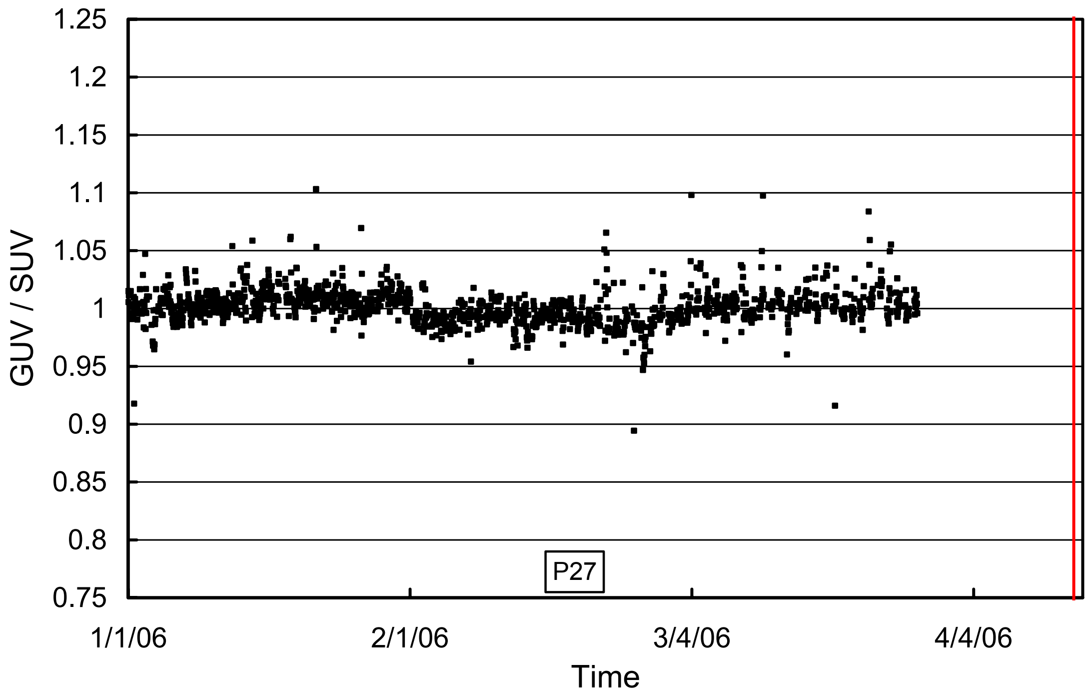

Figure 5.2.5d. *Ratio of GUV-511 and SUV-100 measurements from 2006.*

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 be still a deviation from the correct wavelength scale, but this bias should ideally be the same for all days. Figure 5.2.6 shows differences in the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 724 scans were evaluated. For 96.1% of the days, the change in offset was smaller than ±0.025 nm; for 99.5% of the days, the change in offset was smaller than ±0.055 nm. Two 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 Version 2 Fraunhofer-line correlation method (Bernhard et al., 2004a). Three corrections functions were calculated for different periods and are shown in Figure 5.2.7. The correction functions for Period 1 (6/5/04 - 9/18/05) and Period 3 (11/16/05 - 4/15/06) are virtually identical. The correction function for Period 2 (9/19/05 - 11/15/05) was somewhat different, in particular in the visible.

After data had been wavelength corrected using the shift-function described above, the wavelength accuracy was tested again with the Version 2 Fraunhofer-line correlation method. The results for noontime scans are shown in Figure 5.2.8 for four wavelengths in the UV. The standard deviation of the residual shifts at 320 nm is 0.025 nm. The actual wavelength uncertainty of the instrument may be slightly larger due to wavelength fluctuations during a given day and possible systematic errors of the Fraunhofer-correlation method (Bernhard et al., 2004a).

Data from the external mercury scans do not have a direct influence on the data products, but are part of our instrument characterization routine. Figure 5.2.9 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 0.94 nm FWHM; the bandwidth of the internal scan is 0.70 nm. Internal scans of both periods are shifted by about 0.06 nm to shorter wavelengths with respect to their external counterparts. External scans have the same light path as solar measurements and represent the monochromator bandpass at 296.73 nm.

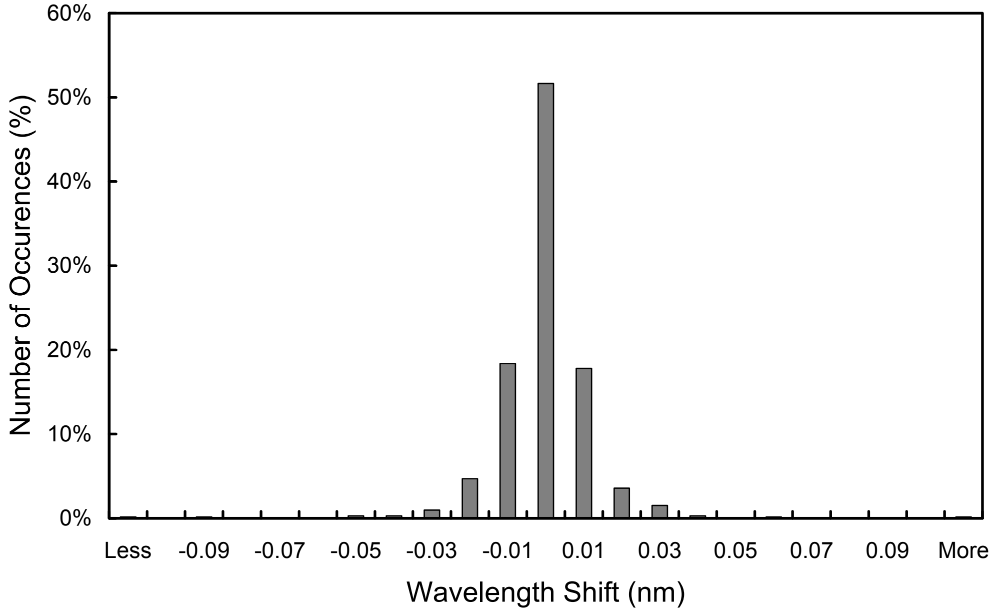

Figure 5.2.6. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. Thus the 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more" means shifts larger than 0.105 nm.*

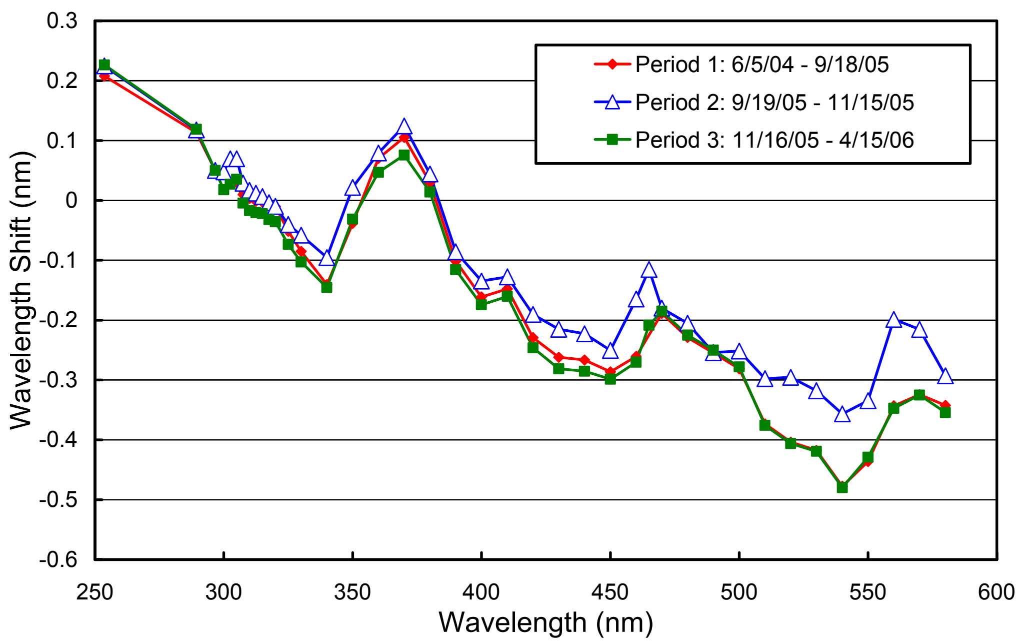

Figure 5.2.7. *Monochromator mapping functions for the period 6/5/04 - 4/15/06.*

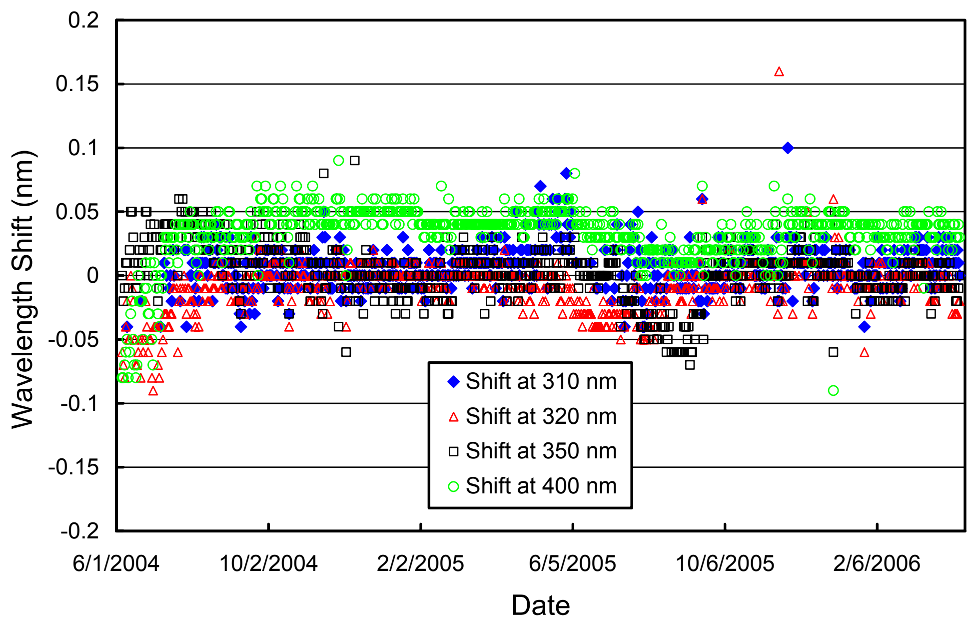

Figure 5.2.8. *Wavelength accuracy check of the final data at four wavelengths by means of Fraunhofer-line correlation. Noontime measurements from every day of have been evaluated.*

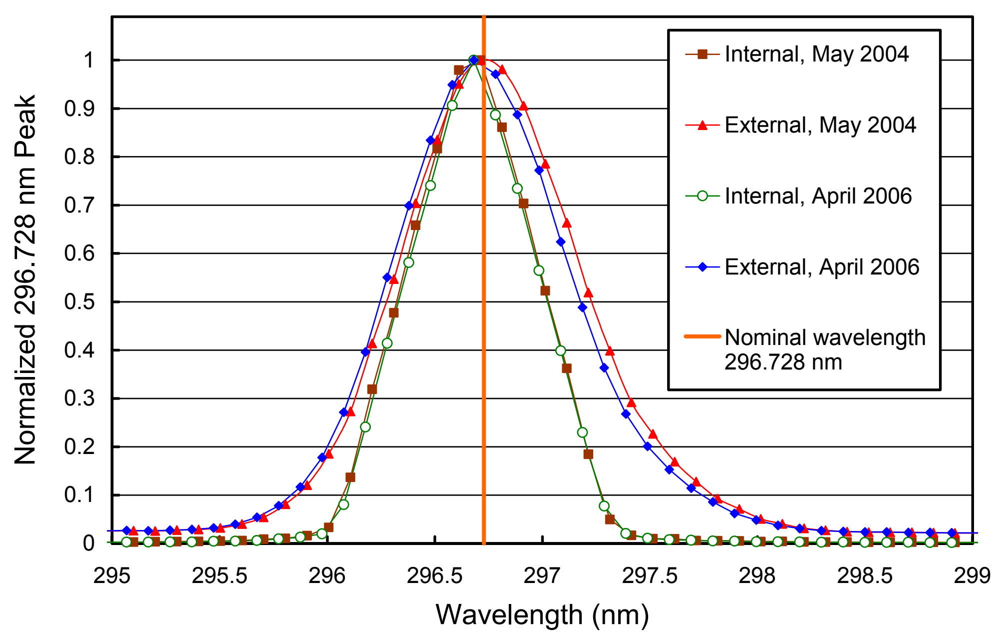

Figure 5.2.9. *The 296.73 mercury line as registered by the PMT from external and internal sources. The wavelength scale is the same as that applied for solar measurements.*

5.2.4. Missing Data

Volume 14:
A total of 19355 scans are part of the published Palmer Volume 14 data set. About 1.1% 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 2.0% of solar scans were lost due to technical problems or because the scan quality was deemed questionable. A total of 60 scans were lost on 10/17/04 and 1/15/05 when the system temperature was erroneously measured at 1000 °C. This triggered a "Level 3 Alarm," causing the system to automatically stop scanning. 66 scans were lost on 10/22/04 when the GPS receiver mistakenly changed the computer time by one day. Comparisons between GUV and SUV measurements revealed discrepancies on several days. These deviations may have been caused by changes in system responsivity or attenuation by snow and ice on the SUV-100 collector. A total of 369 scans were removed from the final data set. The following days are affected: 6/29/04, 6/30/04, 9/19/04, 11/10/04, 11/18/04, 11/19/04, 12/4/04, 12/5/04, 12/28/04, 1/5/05, and 5/28/05.

Volume 15:
A total of 16917 scans are part of the published Palmer Volume 15 data set. About 2.1% of solar scans were superseded by absolute, wavelength, and response scans. About 2.4% of solar scans were lost due to technical problems or because the scan quality was deemed questionable. A total of 12 scans were lost on 9/16/05 due to a power outage. Comparisons between GUV and SUV measurements also revealed discrepancies for the Volume 15 period, and 269 scans were removed from the final data set. Data from following days are affected: 7/12/05, 7/13/05, 7/14/05, 8/4/05, 8/13/05, 8/17/05, 8/18/05, 8/26/05, 8/27/05, 9/8/05, 9/18/05, 10/16/05, 11/9/05, 11/27/05, 11/28/05, 1/2/06, 1/3/06, 1/4/06, 1/14/06, 1/17/06, and 1/18/06.

5.2.5. GUV Data

The GUV-511 radiometer installed next to the SUV-100 was calibrated against final SUV-100 measurements following the procedure outlined in Section 4.3.1. The calibration of the instrument's 320 nm channel drifted by about 10% over the course of the reporting period. The 305 nm channel drifted by 6%, the remaining channels were stable to within ±1%. To correct for these drifts, separate GUV calibrations were established for the Volume 14 and Volume 15 periods. Drifts in published GUV data are smaller than 4%.

Data products were calculated from the calibrated measurements (Section 4.3.2). Figure 5.2.10. shows a comparison of GUV-511 and SUV-100 erythemal irradiance based on final Volume 14 data. Figure 5.2.11 shows a similar comparison for the Volume 15 period. For solar zenith angles smaller than 80°, measurements of the two instruments agree to within ±3.2% (±1σ) with the exception of several outliers, which may partly be caused by sporadic snow and ice accumulation on the either of the two collectors. For example, snow and ice buildup was likely affecting the SUV collector on 1/26/05 and 8/31/05. We advise data users to use SUV-100 rather than GUV-511 data whenever possible, in particular for low-Sun conditions.

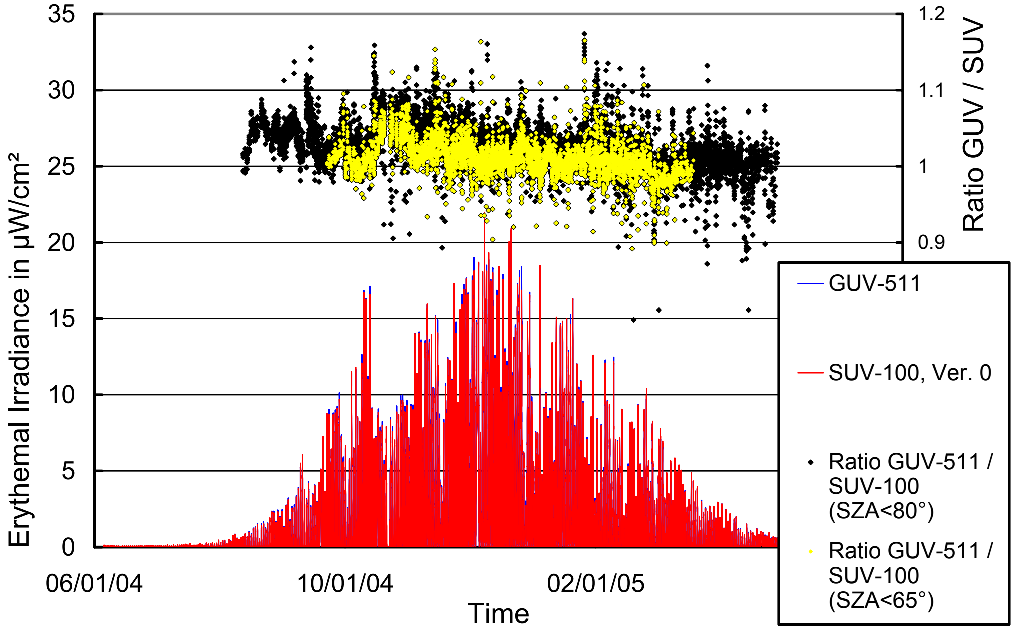

Figure 5.2.10. *Comparison of erythemal irradiance measured by the SUV-100 spectroradiometer and the GUV-511 radiometer of the Volume 14 period. The ratio was filtered for measurements performed at solar zenith angles smaller than 80° (black markers) and 65° (yellow markers).*

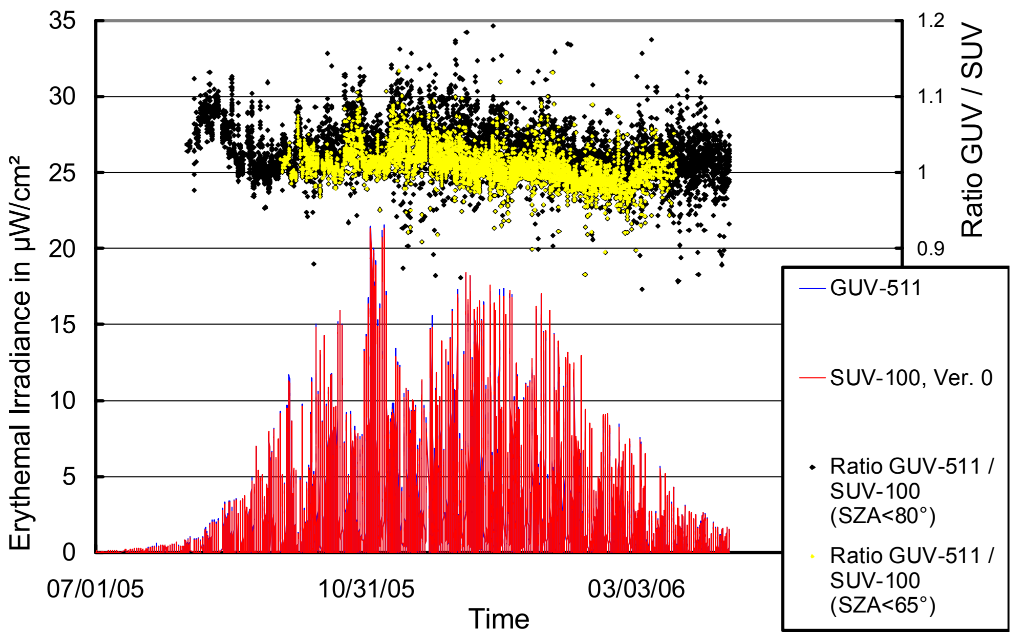

Figure 5.2.11. *Same as Figure 5.2.10 but for Volume 15 period.*

Figure 5.2.12 shows a comparison of total ozone measurements from the GUV-511 radiometer, TOMS Earth Probe Version 8 satellite data and the Ozone Monitoring Instrument (OMI) installed on NASA's AURA satellite. GUV-511 ozone values were calculated as described in Section 4.3.3. There is typically good agreement between the three data sets. For SZA larger than 80°, GUV-511 data become unreliable and should not be used.

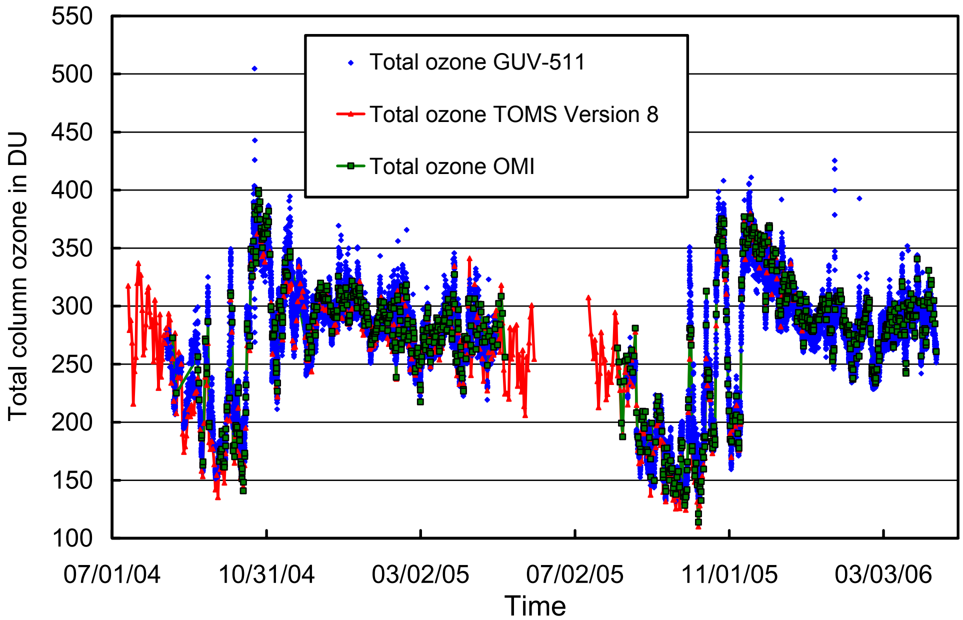

Figure 5.2.12. *Comparison of total column ozone measurements from GUV-511, TOMS Earth Probe and OMI. GUV total ozone data are provided in 15 minute increments for solar zenith angles smaller than 80°.*