5.2. Palmer Station (4/29/06 – 5/9/08)

This sections describes quality control of solar data recorded at Palmer Station between 4/29/06 and 5/9/08. There was no site visit in 2007. Solar data recorded between 4/29/06 and 7/4/07 were assigned to Volume 16; data covering the period 7/5/07 – 5/9/08 are part of Volume 17. Opening and closing calibrations of the 2-year period described in this section were performed on 4/28/06 and 5/10/08, respectively. This is the first period when the system was installed in the new "Terra Lab" building. The laboratory was built in 2005 and 2006 next to the "T-5" building where the system was located previously (Section 3).

The throughput of the SUV-100 monochromator installed during the 2004-2006 season changed abruptly on several occasions. The monochromator was therefore replaced during the site visit in April 2006. Unfortunately, the new monochromator was affected by a similar problem. Sporadic changes in throughput are evident in measurements of PMT currents during response scans. The instability required implementation of a large number of calibration functions (Section 5.2.2). The quality of final SUV-100 data was assessed by comparison with measurements of the collocated GUV-511 radiometer. We conclude from this comparison that drifts in SUV-100 data were successfully removed in general, but the uncertainty in several short periods may be increased by 2-3%.

The Volume 16 and 17 periods resulted in a total of 38541 solar scans. Less than 1% of all scans were lost due to technical problems.

5.2.1. Irradiance Calibration

Traveling standards
Lamp 200W017 was used as the traveling standard at the beginning and the end of the reporting period. Lamp 200W038 was also used as a traveling standard at the end of the period. Lamp 200W017 was originally calibrated by Optronic Laboratories in March 2001. It was compared with the BSI long-term standards M-763 and 200W022 prior to the 2006 Palmer site visit. The calibration of lamp 200W017 agreed with the calibration of the two long-term standards to within ±1%. Lamps M-763 and 200W022 also have Optronic Laboratories calibrations from March 2001. The two lamps were used very sparingly and were kept at BSI at all times.

There is evidence that lamp 200W017 became brighter by 1.5% - 2% between 2006 and 2007. The lamp was recalibrated in May 2007 against a set of four 1000-W FEL lamps with serial numbers H-011, H-013, H-023, and H035. These FEL lamps have been calibrated by NOAA's Central UV Calibration Facility (CUCF) at Boulder, Colo. Lamp 200W038 was also calibrated against the four 1000-W FEL lamps. For more details on the recalibration see Section 5.5.1.

Site standards
The site irradiance standards for 2006-2008 were the lamps 200W007, M-765, and M-700. The three standards were recalibrated in 2006 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 5.2.1. shows a comparison of the recalibrated site standards with lamp 200W017 based on scans performed in April 2006. All measurements agree to within ±1%.

The site standards were compared nine times with each other between 6/3/06 and 3/27/08. The lamps' calibrations agreed to within ±1% until July 2007. From then onward, the level of agreement worsened, indicating that lamps M-700 and 200W007 became brighter by 1-2%. Both lamps were recalibrated against the traveling standards 200W017 and 200W038 using scans performed at the end of the reporting period. The irradiance scale of the four 1000-Watt CUCF lamps was implemented for this calibration transfer. The calibration of lamp M-765 was not changed. Figure 5.2.2 shows a comparison of all lamps based on scans performed on 5/10/08. All measurements agree to within ±0.5%. The three site standards were additionally compared three times between August 2007 and May 2008, and their calibrations agreed with each other to within ±1% on all occasions.

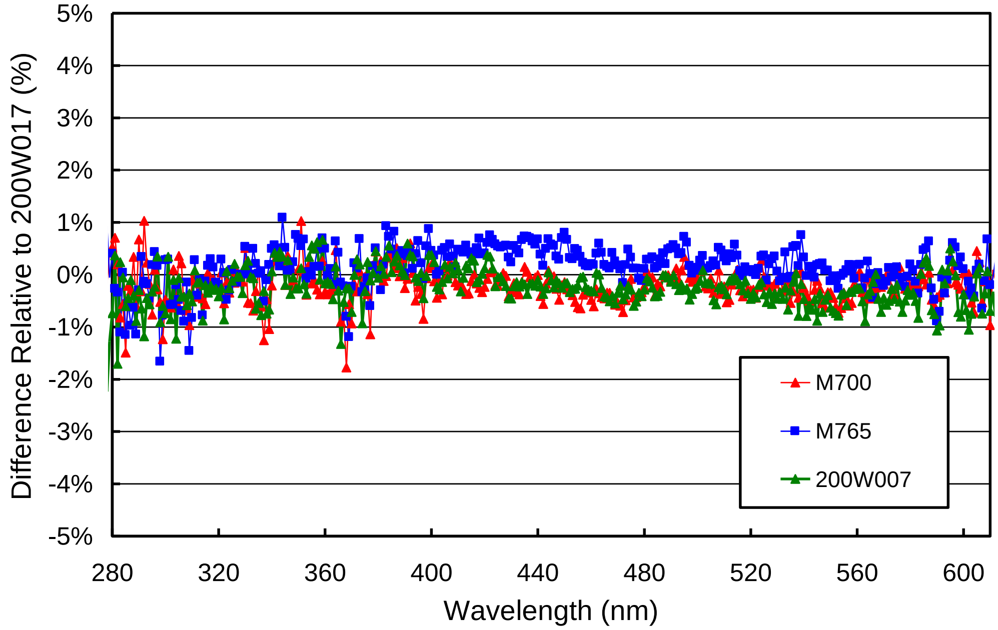

Figure 5.2.1. *Comparison of Palmer lamps M-700, M-765, and 200W007 with the BSI traveling standard 200W017 on 4/28/06. The calibration of lamp 200W017 was established by Optronic Laboratories in March 2001.*

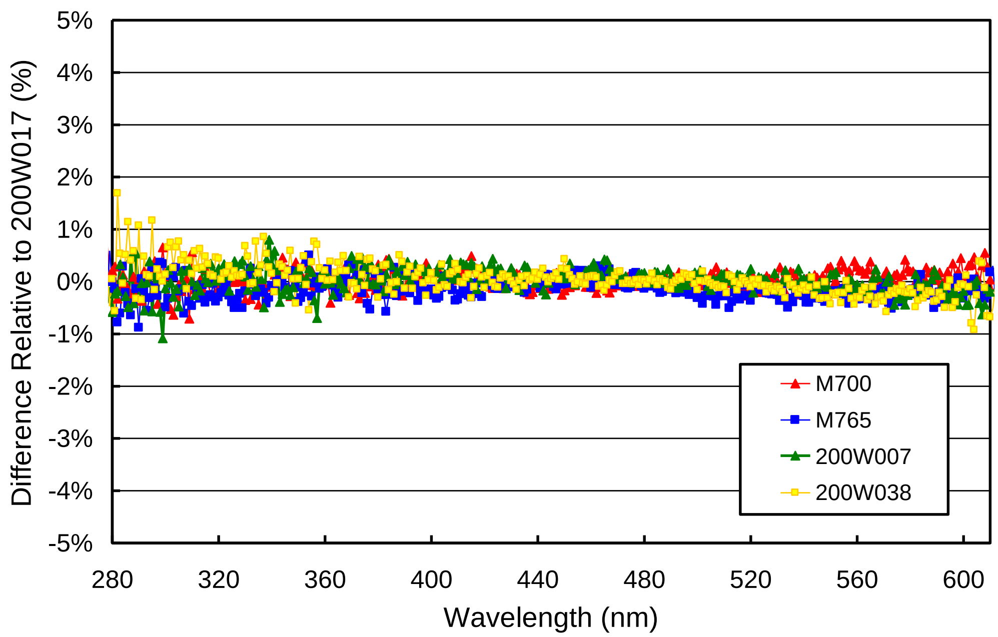

Figure 5.2.2. *Comparison of Palmer lamps M-700, M-765, and 200W007and lamp 200W038 with the BSI traveling standard 200W017 on 5/10/08. The calibrations of lamps 200W017 and 200W038 are traceable to the irradiance scale of four 1000-Watt FEL lamps calibrated by CUCF. Lamps M-700 and 200W007 were calibrated against the two traveling standards. The calibration of lamp M-765 is identical to that used at the beginning of the reporting period.*

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.

Figure 5.2.3 shows TSI measurements and PMT currents at 300 and 400 nm recorded during response scans. TSI and PMT data were normalized to their average values of the reporting period. Measurements of the TSI decreased by 7.5% over the course of the reporting period of almost 25 months. PMT currents were highly unstable, varied by almost 35% between start and end of the reporting period, and showed step-changes on several occasions. The reason of these instabilities were changes in the throughput of the monochromator. The reporting period was broken into 46 calibration periods to correct for these changes, with a different irradiance assigned to the internal lamp for each period. Table 5.2.1 gives an overview of these calibrations and Figure 5.2.4 shows the ratio of the different irradiance spectra to that applied in Period P1. Changes between consecutive periods show little spectral dependence. Several irradiance spectra were also scaled such that ratios between SUV-100 and GUV-511 measurements in the UV become smooth. The scaling is also appropriate for wavelengths in the visible. This method assumes that GUV measurements are stable between absolute calibrations of the SUV-100. This is generally the case. The uncertainty of solar measurements for "scaled" periods is elevated by about 2%.

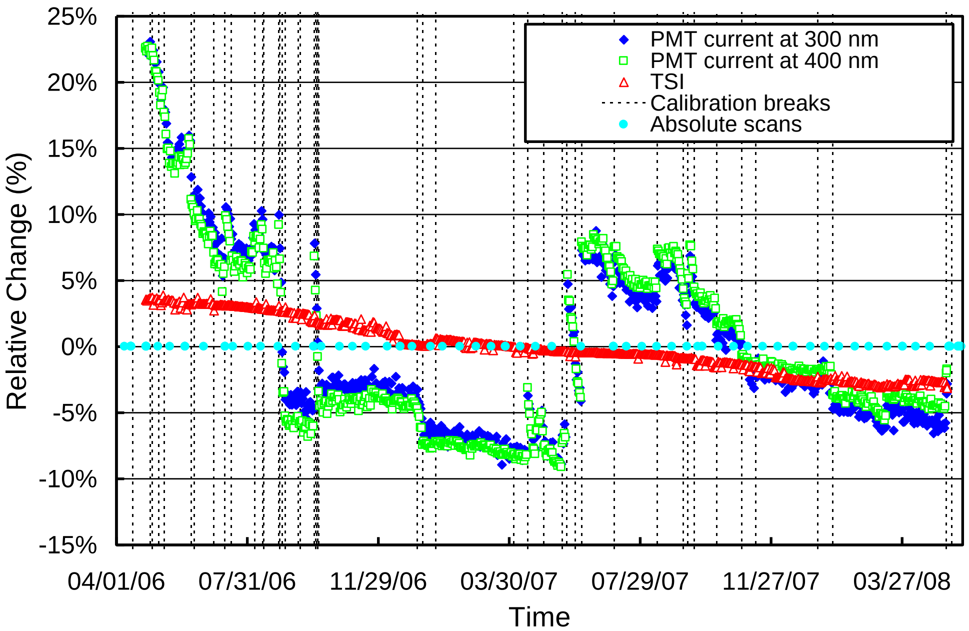

Figure 5.2.3. *Time-series of PMT current at 300 and 400 nm, and TSI signal calculated from measurements of the internal irradiance reference lamp during the Palmer Volume 16 and 17 seasons. All data sets are normalized to their average values. Calibration breaks are indicated by vertical broken lines. Times of absolute scans are indicated by cyan circles.*

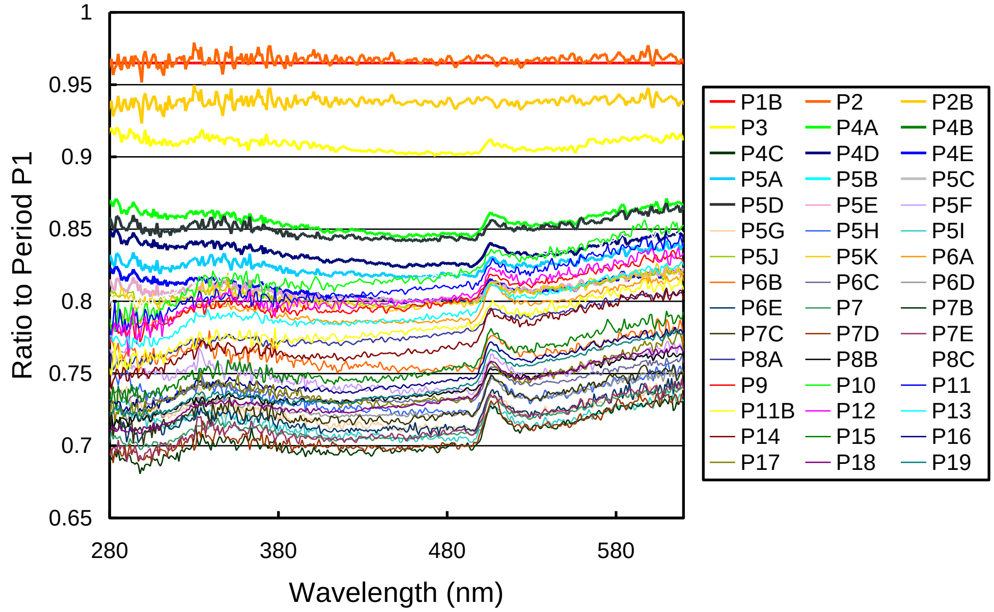

Figure 5.2.4. *Ratios of spectral irradiance assigned to the internal reference lamp for periods P1B – P19, relative to Period P1. The large drift is caused by changes in the monochromator throughput.*

To test the consistency 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 vary between 0.95 and 1.05; the standard deviation is 0.047. Ratios are usually stable to within ±3% within a certain calibration period, with few exceptions.

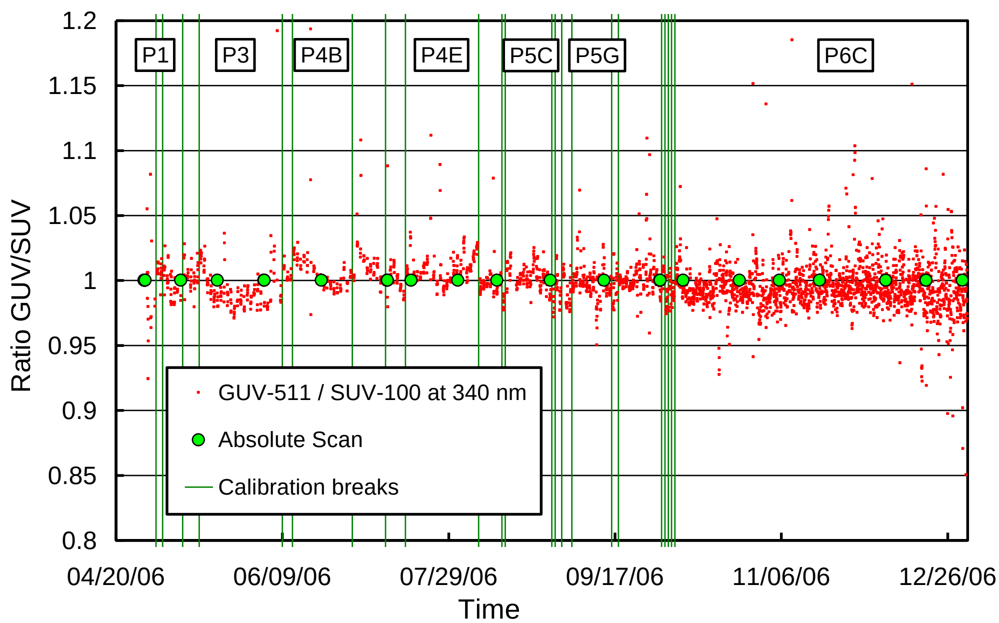

Figure 5.2.5a. *Ratio of GUV-511 and SUV-100 measurements from 2006. Green lines indicate limits of calibration periods.*

Table 5.2.1. Calibration periods for Palmer Volumes 16 and 17 data.

Period name	Period range	Number of Absolute scans	Remarks (Scale factors were determined by comparison of SUV-100 and GUV-511 data.)
P1	04/16/06 - 05/01/06	8	
P1B	05/02/06 - 05/03/06	0	P1 scaled with 0.965
P2	05/04/06 - 05/09/06	1	
P2B	05/10/06 - 05/14/06	0	P2 scaled with 0.97
P3	05/15/06 - 06/08/06	4	
P4A	06/09/06 - 06/11/06	0	P4B scaled with 1.025
P4B	06/12/06 - 06/29/06	6	
P4C	06/30/06 - 07/09/06	0	P4B scaled with 0.97
P4D	07/10/06 - 07/15/06	0	Identical to P4B
P4E	07/16/06 - 08/06/06	0	P4B scaled with 0.97
P5A	08/07/06 - 08/13/06	0	P5B scaled with 0.97
P5B	08/14/06 - 08/14/06	2	
P5C	08/15/06 - 08/28/06	0	P5B scaled with 0.95
P5D	08/29/06 - 08/29/06	0	Identical to P5B
P5E	08/30/06 - 08/31/06	0	P5B scaled with 0.95
P5F	09/01/06 - 09/03/06	1	
P5G	09/04/06 - 09/15/06	0	P5F scaled with 0.965
P5H	09/16/06 - 09/17/06	0	P5F scaled with 0.98
P5I	09/18/06 - 09/30/06	0	P5F scaled with 0.955
P5J	10/01/06 - 10/01/06	0	P5X scaled with 0.955 (Period P5X includes absolute scans performed on 9/30/06)
P5K	10/02/06 - 10/02/06	0	P5X scaled with 0.94
P6A	10/03/06 - 10/03/06	0	P6C scaled with 1.075
P6B	10/04/06 - 10/04/06	0	P6C scaled with 1.03
P6C	10/05/06 - 01/03/07	9	
P6D	01/04/07 - 01/08/07	1	
P6E	01/09/07 - 01/20/07	1	
P7	01/21/07 - 04/02/07	6	
P7B	04/03/07 - 04/15/07	1	
P7C	04/16/07 - 04/30/07	1	
P7D	05/01/07 - 05/17/07	1	
P7E	05/18/07 - 05/21/07	1	
P8A	05/22/07 - 05/29/07	0	P8C scaled with 0.95
P8B	05/30/07 - 06/04/07	0	P8C scaled with 0.90
P8C	06/05/07 - 07/04/07	4	End of Volume 16
P9	07/05/07 - 08/13/07	2	Start of Volume 17
P11	08/14/07 - 09/06/07	1	
P11B	09/07/07 - 09/10/07	0	P11 scaled with 0.965
P12	09/11/07 - 09/16/07	1	
P13	09/17/07 - 10/07/07	3	
P14	10/08/07 - 10/30/07	2	
P15	10/31/07 - 11/12/07	1	
P16	11/13/07 - 01/08/08	6	
P17	01/09/08 - 01/22/08	1	
P18	01/23/08 - 05/06/08	9	
P19	05/07/08 - 05/11/08	10	

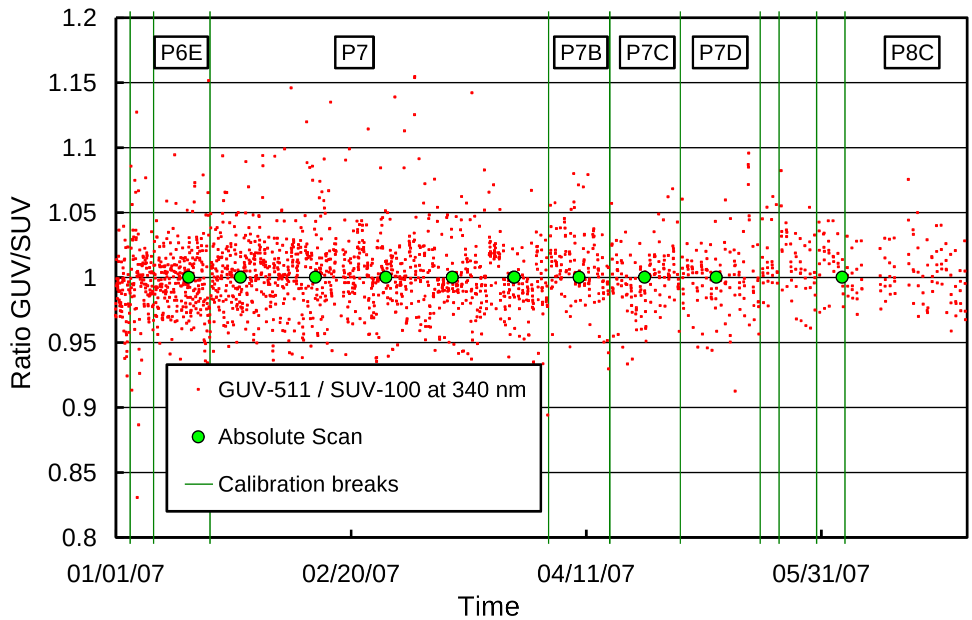

Figure 5.2.5b. *Ratio of GUV-511 and SUV-100 measurements from the first half of 2007.*

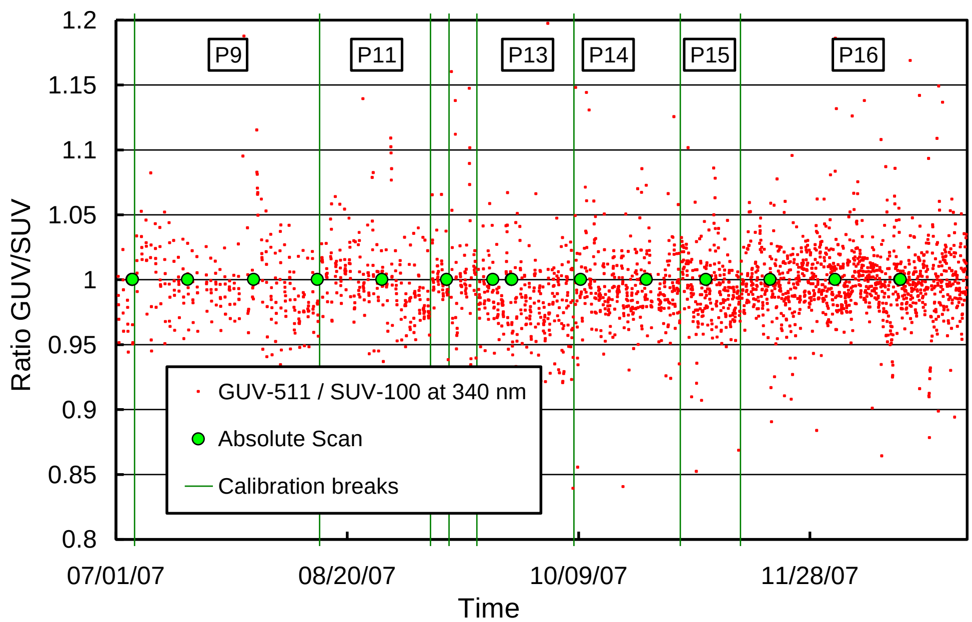

Figure 5.2.5c. *Ratio of GUV-511 and SUV-100 measurements from the second half of 2007.*

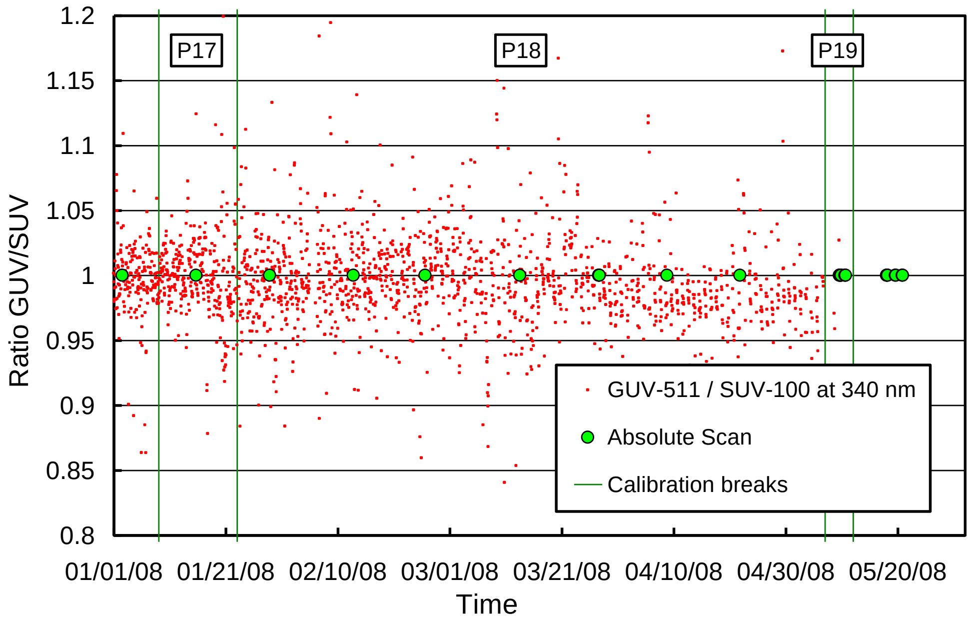

Figure 5.2.5d. *Ratio of GUV-511 and SUV-100 measurements from 2008.*

The calibration of some periods is based on one absolute scan only. Calibration functions for other periods are based on up to 10 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 5.2.6. 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 1.2% for wavelengths larger than 300 nm, indicating good consistency of absolute scans performed within each period.

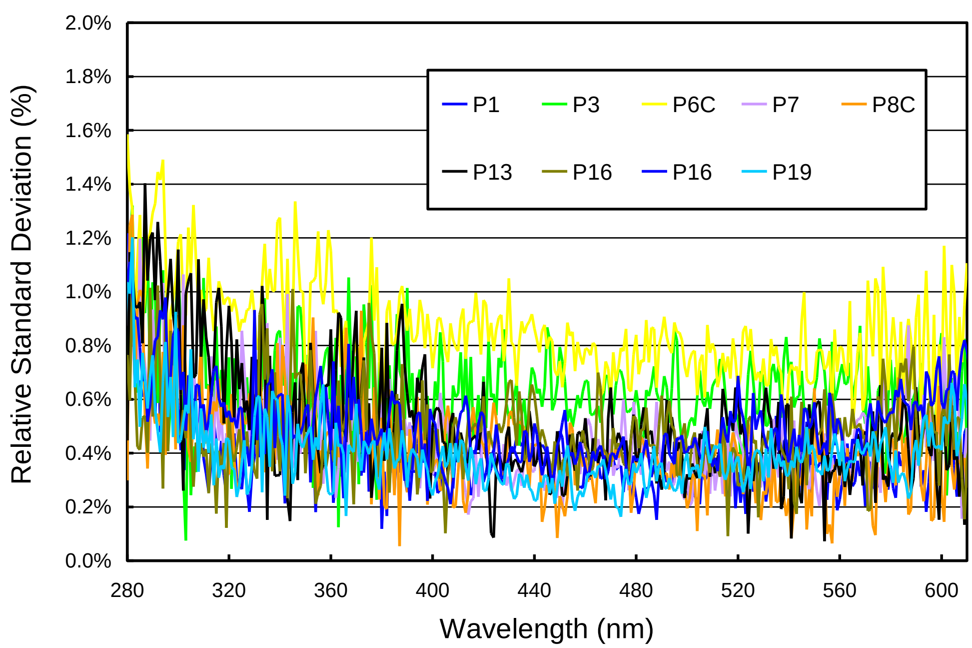

Figure 5.2.6. *Relative standard deviation spectra for periods with more than two absolute scan.*

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 5.2.7 shows differences in the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 849 scans were evaluated. For 92% of the days, the change in offset was smaller than ±0.025 nm; for 99% 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 Version 2 Fraunhofer-line correlation method (*Bernhard et al*., 2004). Five corrections functions were calculated for different periods and are shown in Figure 5.2.8. The five functions are very similar in the UV but deviate slightly 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 5.2.9 for four wavelengths in the UV. The standard deviation of the residual shifts at 320 nm is 0.021 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*., 2004).

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 5.2.10 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 1.2 nm FWHM. This is an unusually large bandwidth; the nominal bandwidth for external scans is 1.0 nm. The bandwidth of the internal scan is 0.75 nm. Internal scans of both periods are shifted by about 0.09 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.

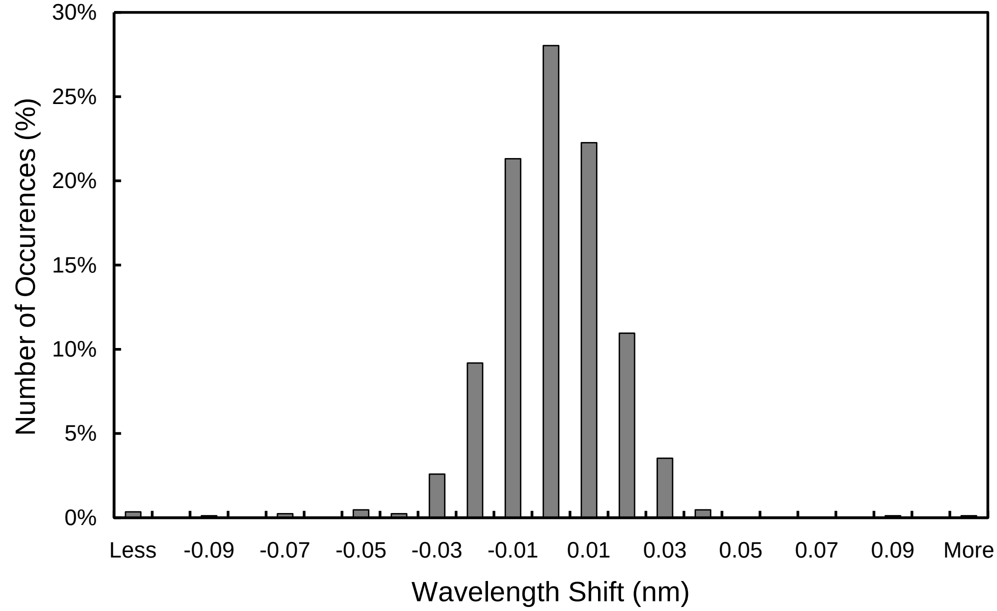

Figure 5.2.7. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. Thus the 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more"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

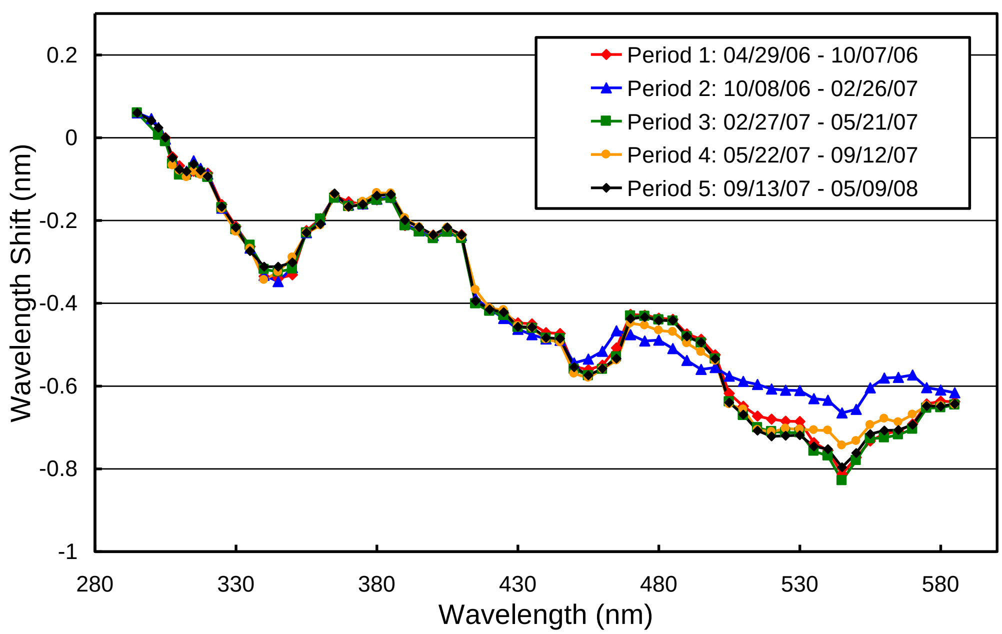

Figure 5.2.8. *Monochromator mapping functions for the period 4/29/06 - 5/9/08.*

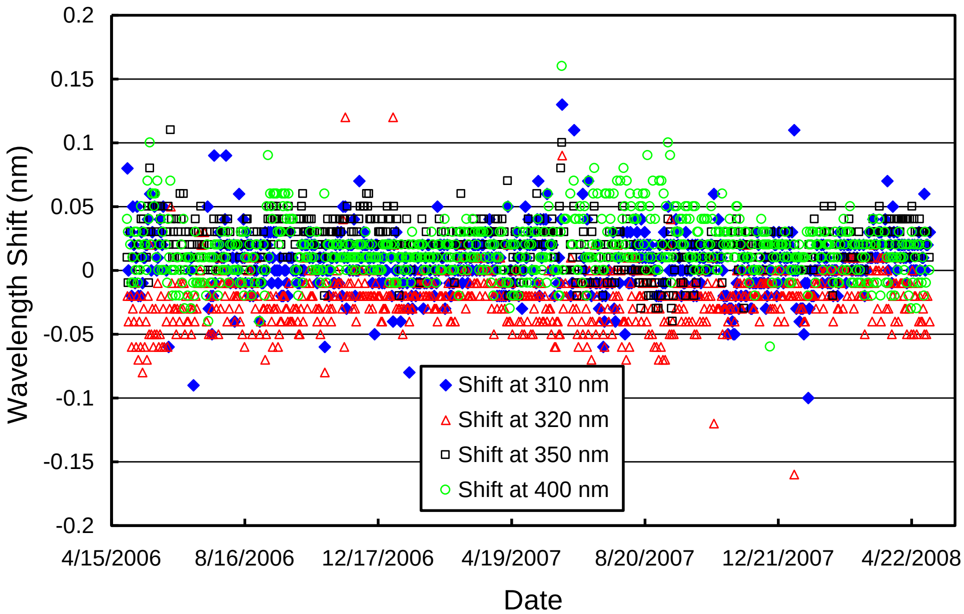

Figure 5.2.9. *Wavelength accuracy check of the final data at four wavelengths by means of Fraunhofer-line correlation. Noontime measurements from every day of have been evaluated.*

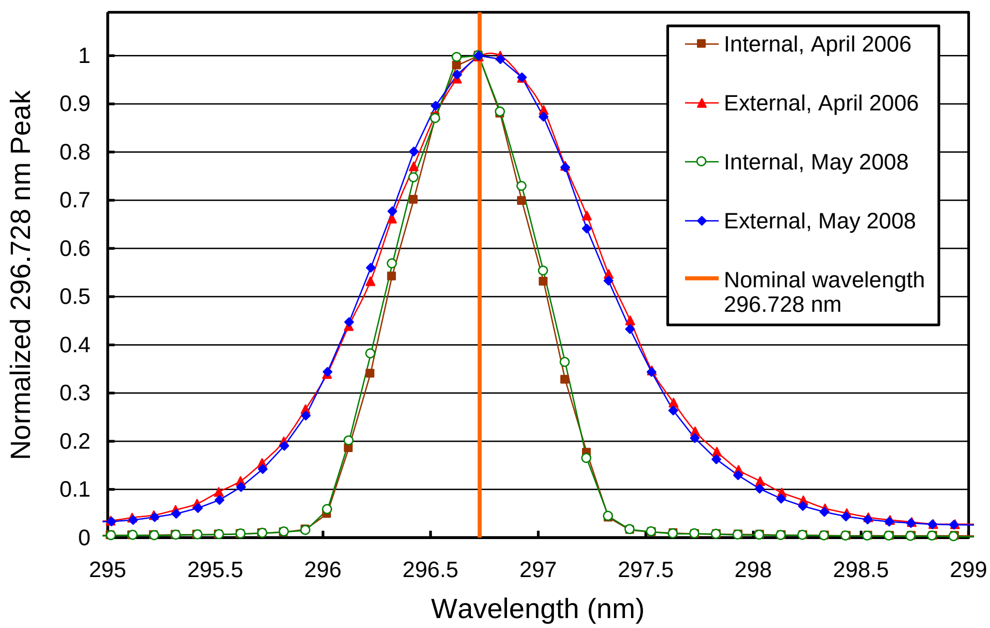

Figure 5.2.10. *The 296.73 mercury line as registered by the PMT from external and internal sources. The wavelength scale is the same as that applied for solar measurements.*

5.2.4. Missing Data

Volume 16
The Palmer Volume 16 dataset includes 20667 solar scans These are 97% of all solar scans possible. Less than 1% of scans were lost because of technical problems. Table 5.2.2 describes gaps in published solar data in more detail.

Volume 17
The Palmer Volume 17 dataset includes 17874 scans. These are 95% of all solar scans possible. Less than 1% of scans were lost because of technical problems, see Table 5.2.2.

Table 5.2.2 Missing scans of Palmer Volumes 16 and 17.

Time Period	Scans missing	Reason
		Volume 16
Throughout period	392	Calibration absolute, wavelength and response scans
04/30/06-05/01/06	43	Installation Power Distribution Unit; coning hard drive
09/18/06	6	Installation Anti-Virus software
09/25/06	17	Software halted for unknown reasons
09/25/06	9	Installation Anti-Virus software
05/21/07-05/22/07	52	Incorrect setting of system time by GPS receiver
06/07/07	16	SUV collector likely covered by snow
06/09/07-06/11/07	62	Instability of responsivity
06/17/07	20	SUV collector likely covered by snow
		Volume 17
Throughout period	336	Calibration absolute, wavelength and response scans
07/19/07	24	SUV collector likely covered by snow
08/15/07-08/16/07	59	Measurements abnormally high
10/27/07	13	SUV collector likely covered by snow
11/19/07	17	SUV collector likely covered by snow

5.2.5. GUV Data

The GUV-511 radiometer was installed next to the SUV-100 and 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 9% over the course of the reporting period. The remaining channels were stable to within ±1%. To correct for the drift of the 320 nm channel, four different GUV calibrations were established for the Volume 16 and Volume 17 periods. Drifts in published GUV data are smaller than 2%.

Data products were calculated from the calibrated measurements (Section 4.3.2). Figure 5.2.11. shows a comparison of GUV-511 and SUV-100 erythemal irradiance based on final Volume 16 data. Figure 5.2.12 shows a similar comparison for the Volume 17 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. We advise data users to use SUV-100 rather than GUV-511 data whenever possible, in particular for low-Sun conditions.

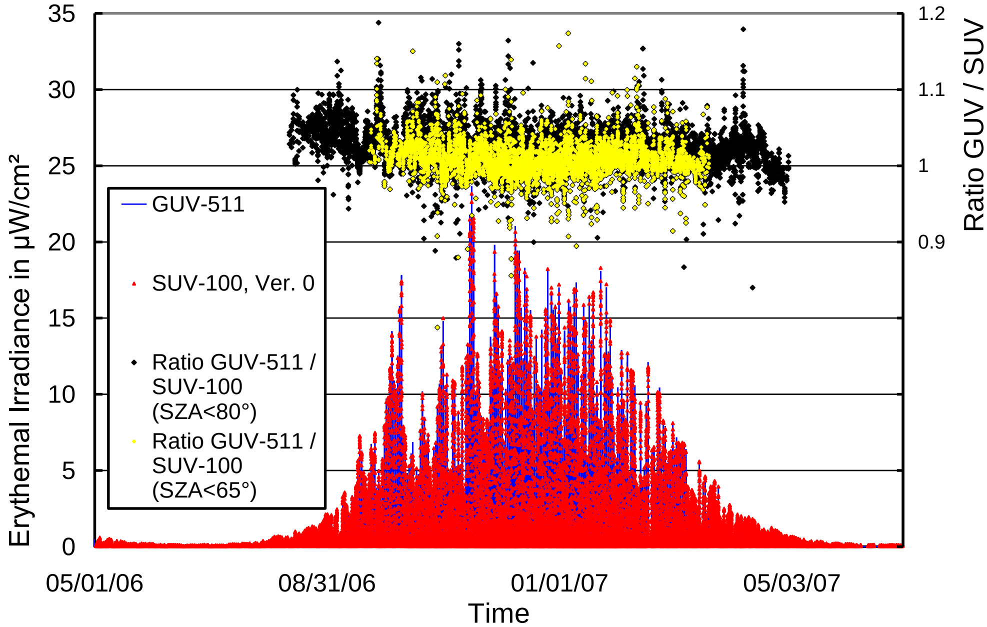

Figure 5.2.11. *Comparison of erythemal irradiance measured by the SUV-100 spectroradiometer and the GUV-511 radiometer of the Volume 16 period. The ratio was filtered for measurements performed at solar zenith angles smaller than 80° (black markers) and 65° (yellow markers).*

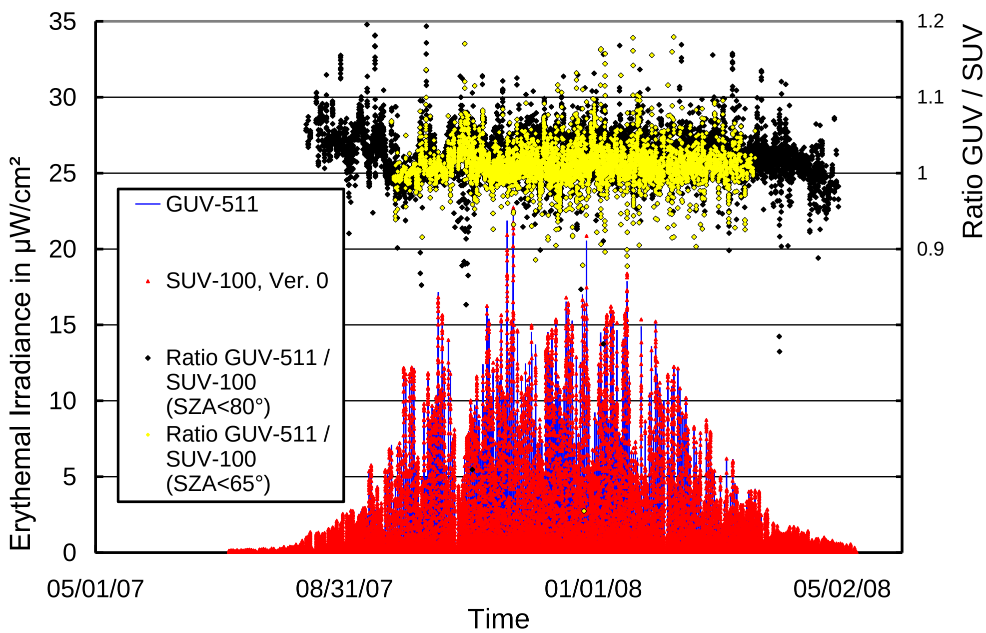

Figure 5.2.12. *Same as Figure 5.2.10 but for Volume 15 period.*

Figure 5.2.13 shows a comparison of total ozone measurements from the GUV-511 radiometer, the Ozone Monitoring Instrument (OMI) installed on NASA's AURA satellite and SUV-100 Version 2 data. 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.

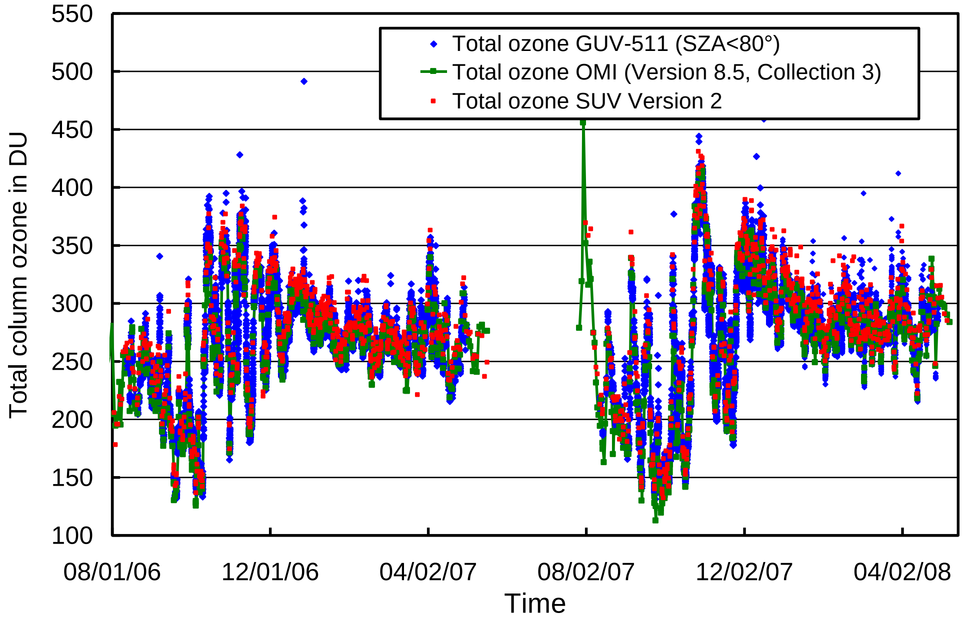

Figure 5.2.13. *Comparison of total column ozone measurements from GUV-511, OMI, and SUV-100. GUV total ozone data are provided in 15 minute increments for solar zenith angles smaller than 80°. OMI data are from the "Version 8.4 Collection 3" data edition, which is approximately 2% smaller than the original OMI data release. SUV-100 data are from the "Version 2" data edition.*