5.6. Barrow, Alaska (1/13/07 – 11/28/07)

This section describes quality control of solar data recorded at Barrow between 1/13/07 and 11/28/07. Start and end of the data series are defined by the periods of winter darkness when the Sun remains more than 3° below the horizon. There was no visit to the site during this period, but the three on-site calibration standards were recalibrated. In addition to SUV-100 measurements, data from a GUV-511 multifilter instrument is available for the period 1/1/07 – 12/31/07. A total of 16506 scans are part of the Barrow Volume 16 dataset. 12.5% of all possible solar scans were lost due to technical problems.

Data quality and availability was affected by several issues:

- **Communication problem of computer with peripherals**
  From the start of the reporting period, communication between the control computer and the system's high-resolution analog-to-digital converter (HRAD) was intermittent. The cause of the fault could not be determined, and the problem was solved by installing a new computer on 4/10/07. The problem led to a significant loss of data from February and March.

- **Drifting and instable internal irradiance standards**
  The internal reference lamp became unstable on 8/21/06 (see Volume 15 Operations Report) and could not be used from then onward for tracking changes of the system's responsivity. The lamp was replaced on 1/30/07. The signal produced by the new lamp also showed short-term fluctuations of about 10%. On 3/3/07, the lamp's random variations ceased for no apparent reason. Between March and December 2007, the lamp became steadily brighter at a rate of 1.2% per month. This rate of increase is still beyond typical changes for internal lamps, but the effect could be corrected.

- **Non-availability of calibration standards**
  The three on-site standards of spectral irradiance (lamps 200W009, M-762, and M-699) were sent to Optronic Laboratories for recalibration at the end of July 2007. It was planned that the lamps are back in service one month later. There were unfortunately delays and the lamps could not be returned for the remainder of the season. Between August and November, the system was vicariously calibrated against the GUV-511 radiometer. The calibration was further assessed by comparing measurements of the SUV-100 with radiative transfer model calculations. We conclude that the uncertainty of published solar data from August to November is increased by about ±5%.

- **Insufficient temperature stabilization**
  Between 8/22/07 and 9/14/07, temperatures inside the instrument enclosure exceeded the set value by several degrees due to overheating of the laboratory located below the SUV-100. The monochromator temperature, which is normally maintained at 33 °C, exceeded 36 °C on several occasions. The maximum temperature was 40 °C. Comparisons with the GUV-511 radiometer indicate that the responsivity of the SUV-100 spectroradiometer was decreased by 30% when the temperature was 40 °C. Typical enhancement are in the range of 5-10% and could be corrected by adjusting the instrument's calibration accordingly. Periods with larger change in responsivity were excluded from the published data set.

- **Defective wavelength indicator**
  The wavelength indicator of the monochromator jammed on 7/21/07 and was removed on 7/27/07. Data from this period had to be discarded.

- **Time error**
  The computer time was reset by the system's GPS receiver by one day on 6/3/07. Data from this day had to be excluded from the published data set.

- **HRAD error**
  The HRAD did not work correctly between 9/14/07 and 9/17/07. No data were recorded.

5.6.1. Irradiance Calibration

The site irradiance standards of the reporting period were the lamps 200W009, M-762, and M-699. All lamps have been calibrated by Optronic Laboratories (OL) in March 2001. They were recalibrated by OL in September 2007. The OL scale from 2001 referred to the 1990 source-based scale of the National Institute of Standards and Technology (NIST1990, *Walker et al*., 1987). All data of the NSF UVSIMN refer to this scale. The OL scale from 2007 referred to the 2000 detector-based NIST scale (NIST2000, *Yoon et al*., 2002). The NIST2000 scale is about 1.3% larger than the NIST1990 scale. Data of certificates issued in 2007 by OL were converted to the NIST1990 scale and compared with the OL calibration from 2001. Ratios of the two data sets are shown in Figure 5.6.1 for the three lamps. The calibrations agree to within ±1.5% for all lamps, but there is a systematic difference in the UV between results for lamp 200W009 and the two other lamps. A similar difference was not observed when comparing the three lamps at Barrow on 4/13/07 and 6/30/07 (Figure 5.6.2 and 5.6.3).

Several lamps calibrated by OL in 2007 were also compared at BSI with four 1000-Watt FEL lamps provided by the Central UV Calibration Facility (CUCF) at Boulder. Results indicated a 1.5% - 3.0% difference between the 2007 OL scale and the CUCF scale. Calibrations provided by OL in 2001 agreed better with the CUCF scale. As of this writing, the discrepancies are still unresolved and we decided to base calibrations of solar data collected at Barrow in 2007 on the OL scale from 2001.

Figures 5.6.2 and 5.6.3 show comparisons of the three site standards performed on 4/13/07 and 6/30/07. Lamps 200W009 and M-762 agreed with each other to within ±1% on both occasions. The calibration of lamp M-699 differed by 2% in the UV from the other two lamps.

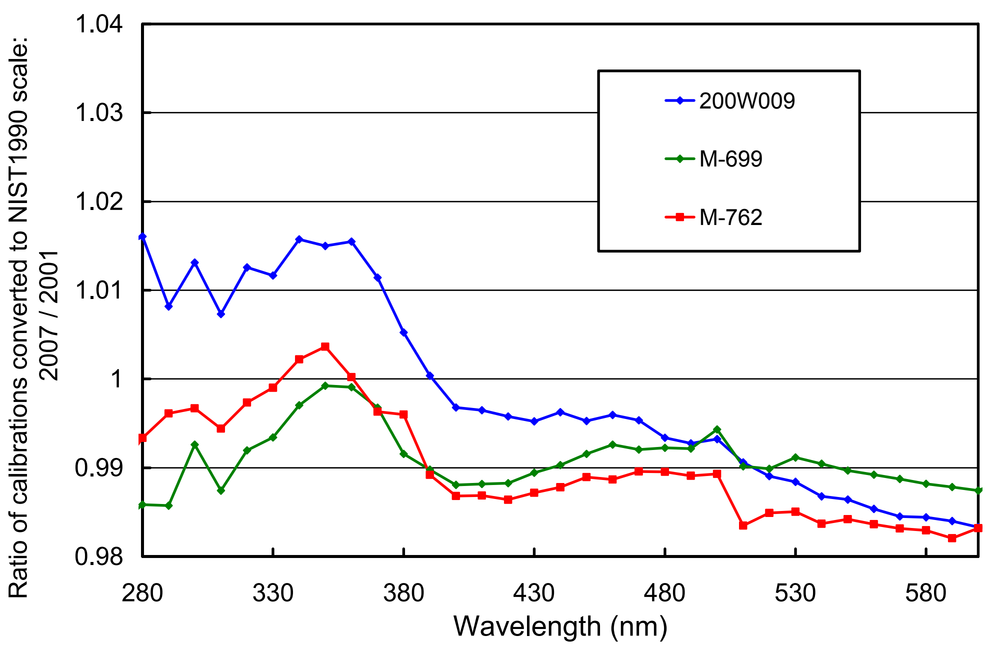

Figure 5.6.1. *Comparison of spectral irradiance value of lamps 200W009, M-699, and M-762 provided by Optronic Laboratories in 2001 and 2007. Data from certificates issued in 2007 were converted to the NIST1990 scale and ratioed to data from the 2001 calibration.*

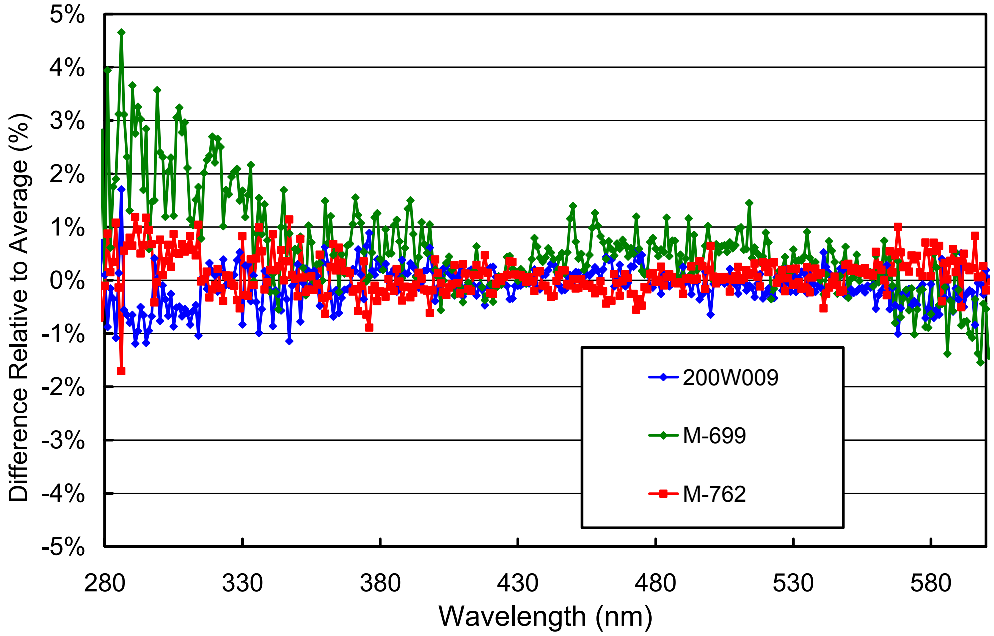

Figure 5.6.2. *Comparison of lamps 200W009, M-762, and M-699 on 4/13/07.*

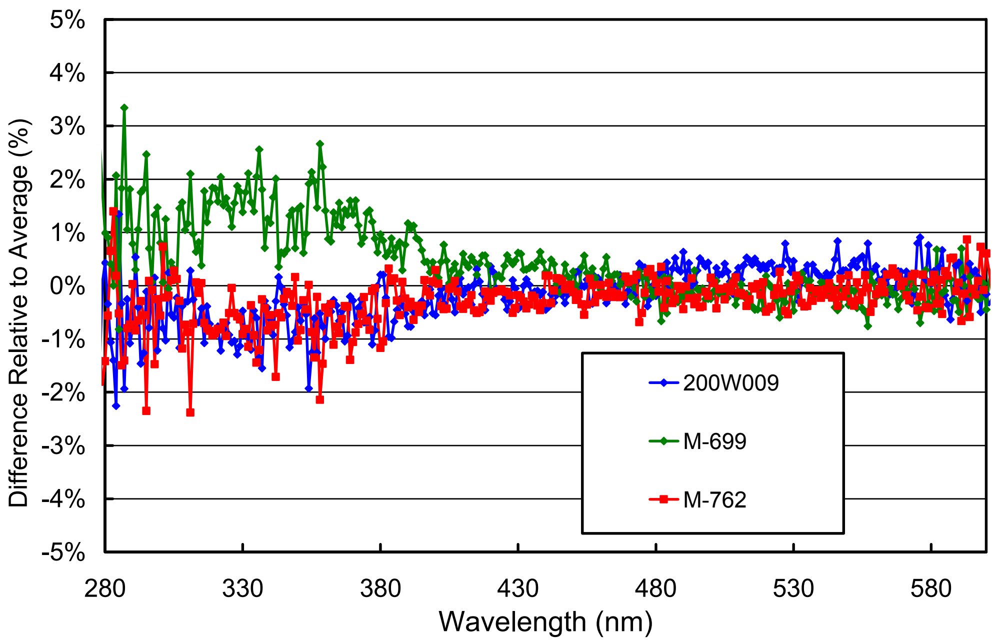

Figure 5.6.3. *Comparison of lamps 200W009, M-762, and M-699 on 6/30/07.*

5.6.2. Instrument Stability

The radiometric stability of the SUV-100 spectroradiometer over time was monitored with calibrations utilizing the site irradiance standards, comparisons with the GUV-511 radiometer, and daily response scans of the internal irradiance reference lamp. The stability of this lamp was in turn monitored with the TSI sensor. By logging the PMT currents at several wavelengths during response scans, changes in monochromator throughput and PMT sensitivity can be detected.

The assessment of stability during 2007 was compromised by the fact that 200-Watt calibration standards were not available between August and November. In addition, the internal 45-Watt that was installed until 1/30/07 was unstable, and the replacement also suffered from fluctuations of about 10% until 3/3/07. Thereafter, the lamp's random variations ceased but its irradiance was affected by a relatively large drift-rate of 1.2% per month. Figure 5.6.4 shows changes in TSI readings and PMT currents at 300 and 400 nm that were derived from the daily response scans. TSI measurements document the instabilities of the two internal lamps. From 3/3/07 onward, PMT currents generally track the TSI measurement, indicating that monochromator throughput and PMT sensitivity changed by less 5% between March and December.

Because of the non-availability of calibration standards and the drifts of the internal lamps, measurements of the GUV-511 radiometer became the most important resource for assessing and correcting changes in the responsivity of the SUV-100 system. The procedure involved a multi-step process: first, a calibration was transferred from the SUV-100 to the GUV-511 as described in Section 4.3.1 based on data from the period March - July. The calibration of the SUV-100 could be well established with absolute scans for this period. Second, measurements of the two radiometers performed between August and November were compared. Third, ratios at the GUV's nominal wavelengths were inter- and extrapolated to wavelengths between 280 and 600 nm. Fourth, calibration functions of the SUV-100, which had been established from absolute scans, were scaled with the interpolated ratios of GUV/SUV from Step 3 and applied to periods without absolute scans. This procedure resulted in a total of 16 calibration functions. Figure 5.6.5 shows the ratio of those functions relative to the function of Period P2 (2/1/07 - 4/19/07). More details are provided in Table 5.6.1. Some changes in responsivity were likely caused by abrasion of paint from the system's shutter, which was collecting on the system's relay lens. Similar problems have also been reported in previous operations reports. Periods P5I and P5J were also affected by excess monochromator temperatures.

After applying these calibration functions, SUV-100 data were again compared with GUV-511 measurements. The ratio of final GUV and SUV data at 340 nm is shown in Figure 5.6.6. Data of both instruments are typically consistent at the ±5% level. Larger fluctuations can be observed during the period of excessive monochromator temperatures (8/22/07 - 9/14/07). SUV-100 data from 8/24/07 and 8/25/07 were low by up to 30% and were not published. Figure 5.6.7 indicates that the rise in monochromator temperature from 33 °C to 36.5 °C on 9/13/07 and 9/14/07 increased the ratio of GUV/SUV by about 13%. Hence data from this day should also not be used.

The uncertainty of data from the period when the vicarious GUV-based calibration was applied is increased by about ±5%. This increase is due to uncertainties of the interpolation (step three), drifts of the SUV-100 within calibration periods, and possible long-term changes in the responsivity of the GUV-511 radiometer. The latter source of uncertainty is small because the calibration constant of the GUV's 340 nm channel has not changed by more than 1% during the last three years.

Final SUV-100 data were also compared with the instrument's TSI sensor. These data indicate that SUV-100 measurements are biased low by up to 7% in some periods (last column of Table 5.6.1). The TSI sensor is integral to the SUV-100 and also susceptible to temperature changes. Comparisons during periods with elevated temperature have to be treated with caution.

As a last check of data quality, SUV-100 measurements were compared with radiative transfer calculations. These calculations are part of Version 2 processing (www.biospherical.com/NSF/Version2/). For February - July and October, the ratio of measured and modeled data was generally within the range observed in past years. UV measurements during clear-sky periods in August and September tended to be lower than the model by up to 5%. An accurate assessment is difficult because of the sparsity of cloud-free days in the fall.

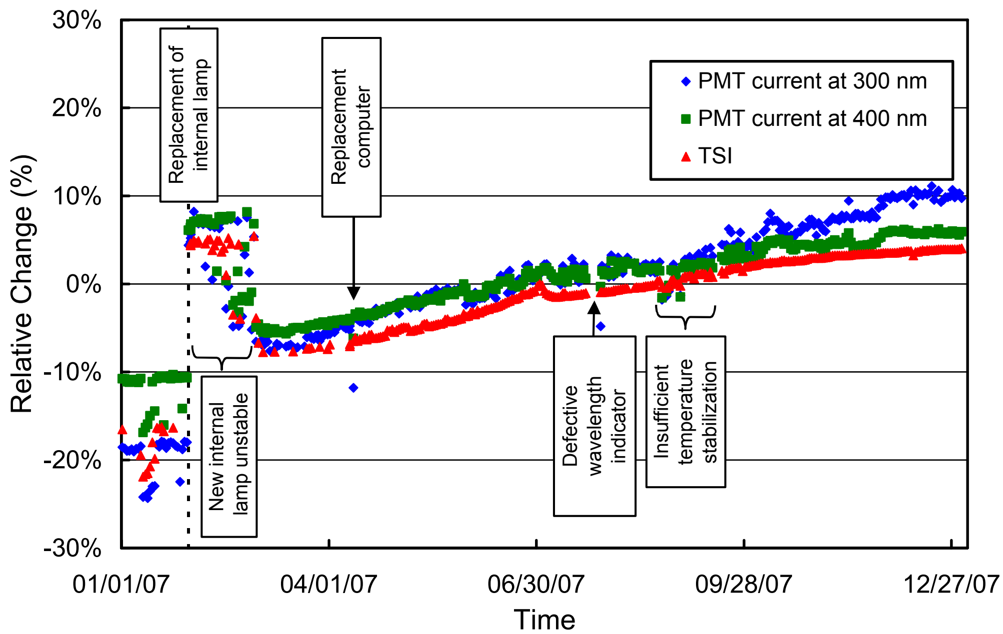

Figure 5.6.4. *Time-series of PMT current at 300 and 400 nm, and TSI signal extracted from measurements of the internal irradiance standard at Barrow between 1/1/07 – 12/31/07. All data sets are normalized to their average.*

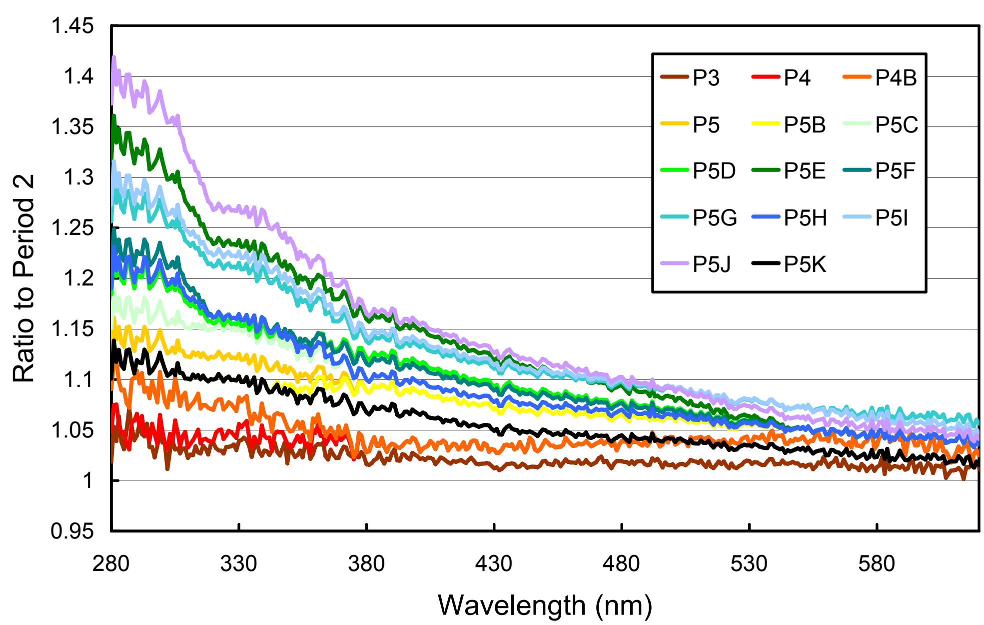

Figure 5.6.5. *Ratios of spectral irradiance values assigned to the internal reference lamp during the Periods P3 – P5K, relative to Period P2.*

Table 5.6.1: Calibration periods of Barrow Volume 16 data.

Period	Period range	Scans*	Remarks	Possible Bias+
P1	01/13/07-01/31/07	2	Period affected by unstable internal lamp; absolute calibration based on scans performed on 11/18/06 and 12/14/06	
P2	02/01/07-04/19/07	4	Period affected by unstable internal lamp	
P3	04/20/07-05/18/07	2		
P4	05/19/07-05/28/07	1		
P4B	05/29/07-06/03/07	0	Period P4, scaled	
P5	Various Times	6	Absolute scans performed between 6/6/07 and 7/13/07; applied to periods: 06/07/07-06/14/07, 06/22/07-07/27/07, 09/08/07-10/09/07, 10/17/07-12/31/07	–2% to –5% between 9/12/07 and 9/14/07
P5B	06/04/07-06/06/07	0	Period P5, scaled	
P5C	06/15/07-06/21/07	0	Period P5, scaled	
P5D	07/28/07-08/01/07	0	Period P5, scaled	+2%
P5E	08/02/07-08/05/07	0	Period P5, scaled	+7%
P5F	08/06/07-08/11/07	0	Period P5, scaled	+3%
P5G	08/12/07-08/13/07	0	Period P5, scaled	
P5H	08/14/07-08/23/07	0	Period P5, scaled; affected by large changes in temperature	
P5I	08/25/07-08/28/07	0	Period P5, scaled; affected by large changes in temperature	
P5J	09/01/07-09/07/07	0	Period P5, scaled	+7%
P5K	10/10/07-10/16/07	0	Period P5, scaled	

* Number of absolute scans performed in given period.
+ Indicated by TSI sensor. Positive values suggest that SUV-100 UV-A data are too high.

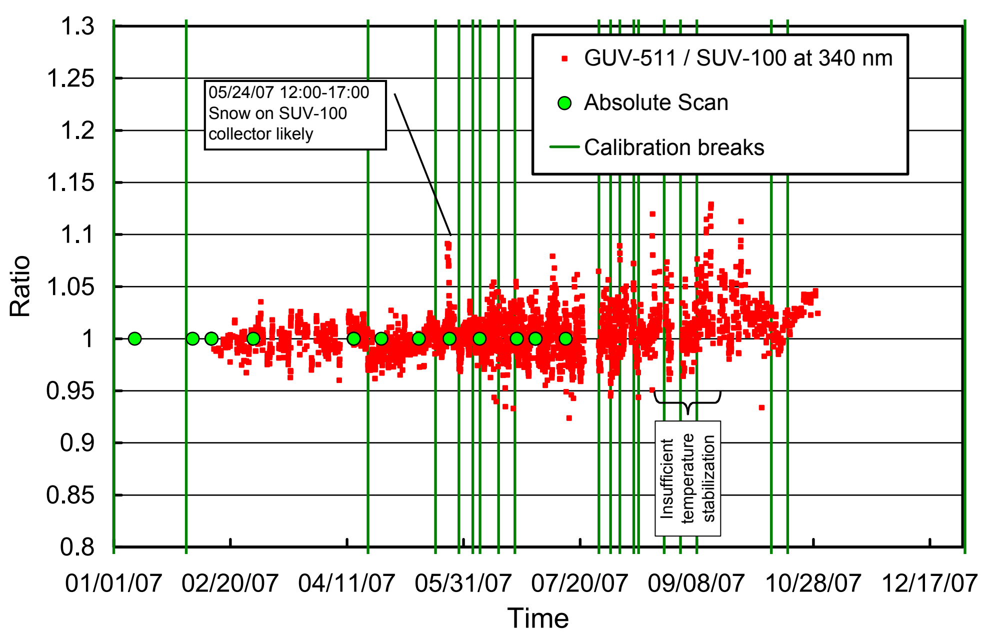

Figure 5.6.6. *Ratio of GUV-511 measurements of the 340-nm channel to SUV-100 measurements. The latter were weighted with the spectral response function of the 340-nm GUV-511 channel. Only data for SZA<85° are plotted. Times of absolute scans and calibration breaks are also indicated.*

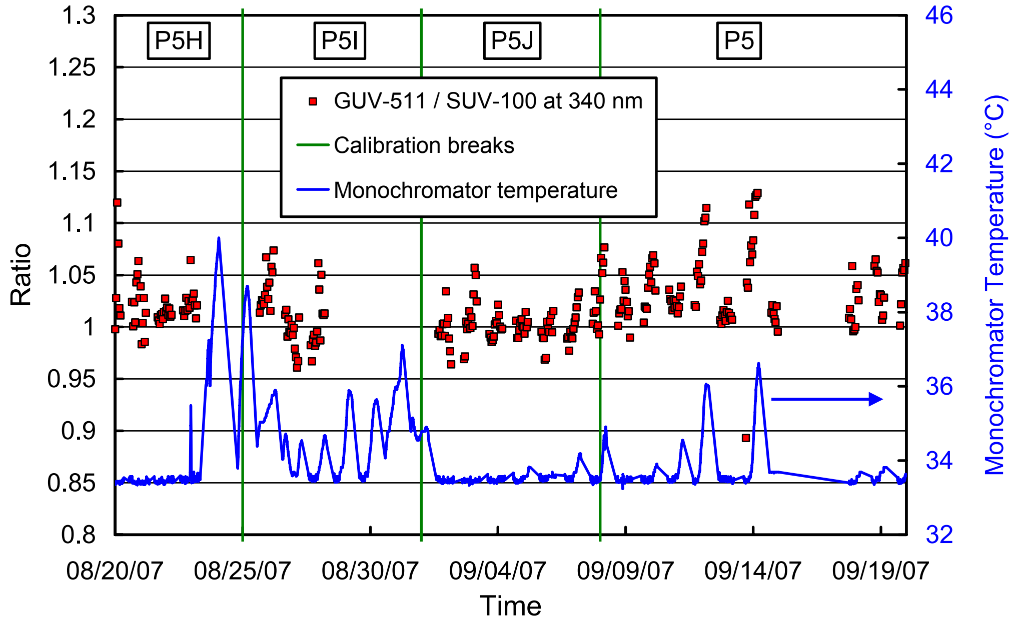

Figure 5.6.7. *Left axis: Ratio of GUV-511 measurements of the 340-nm channel to SUV-100 measurements weighted with the spectral response function of the 340-nm GUV-511 channel. Right axis: Monochromator temperature.*

Figure 5.6.8 presents ratios of standard deviation and average spectra, calculated from individual absolute scans performed in periods with more than one scan. These ratios are useful for estimating the variability of calibrations in each period. The variability is less than 2% for all periods.

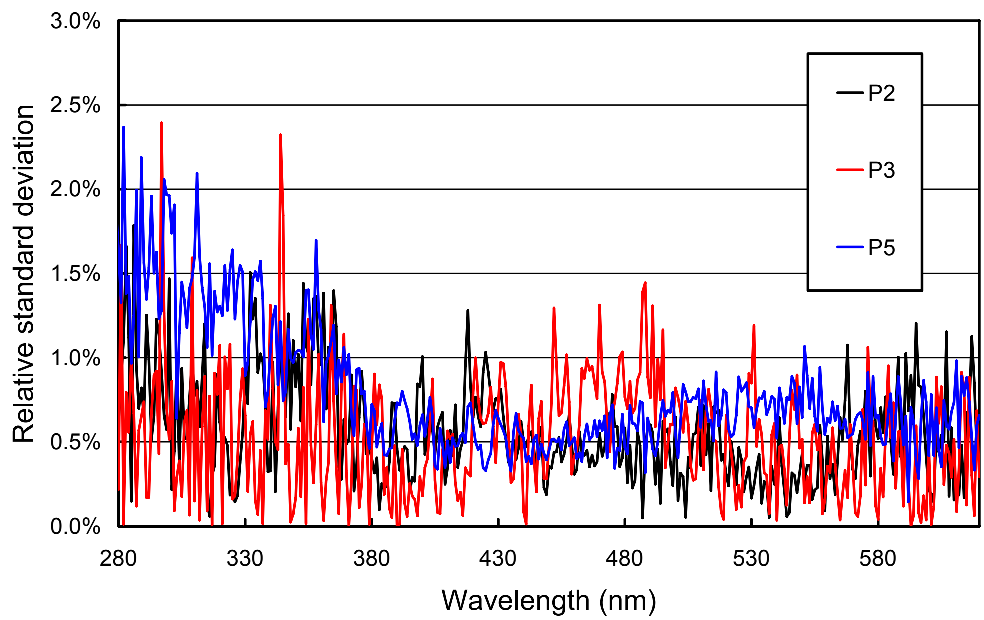

Figure 5.6.8. *Ratio of standard deviation and average spectra calculated from absolute calibration scans.*

5.6.3. 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. Figure 5.6.9 shows the differences in the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 377 pairs were evaluated. In 93% (96%) of all cases, the change in offset was smaller than ±0.025 nm (±0.055 nm). This is a remarkable good consistency considering the observed variations in monochromator temperature. Differences for 14 pairs were larger than ±0.1 nm and were caused by the change of the computer (3), the jammed wavelength indicator (5), the HRAD failure (2), and operator intervention (4). Data were corrected accordingly.

Two functions for correcting the non-linearity of the monochromator's wavelength drive were implemented and are shown in Figure 5.6.10. The functions were calculated with the Version 2 Fraunhofer line correlation method (*Bernhard et al*., 2004). Data were corrected with these functions and again tested with the correlation method. Results for four wavelengths in the UV and one in the visible are shown in Figure 5.6.11. Residual shifts are typically smaller than ±0.05 nm. Wavelengths accuracy is only little affected by the monochromator's temperature variations.

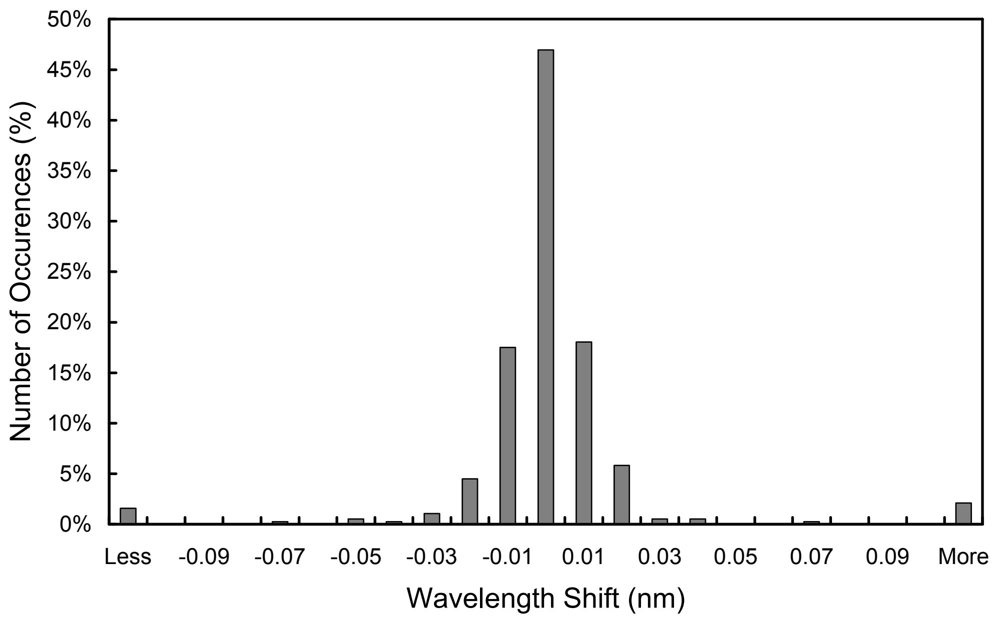

Figure 5.6.9. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. Thus the 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more" means shifts larger than 0.105 nm.*

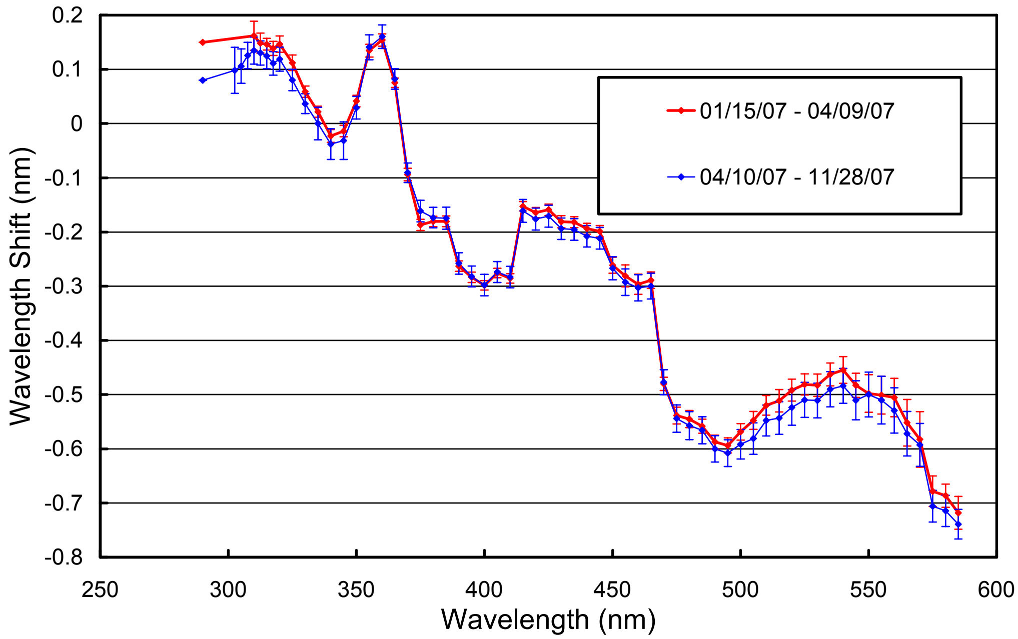

Figure 5.6.10. *Monochromator non-linearity correction functions for Barrow Volume 16.*

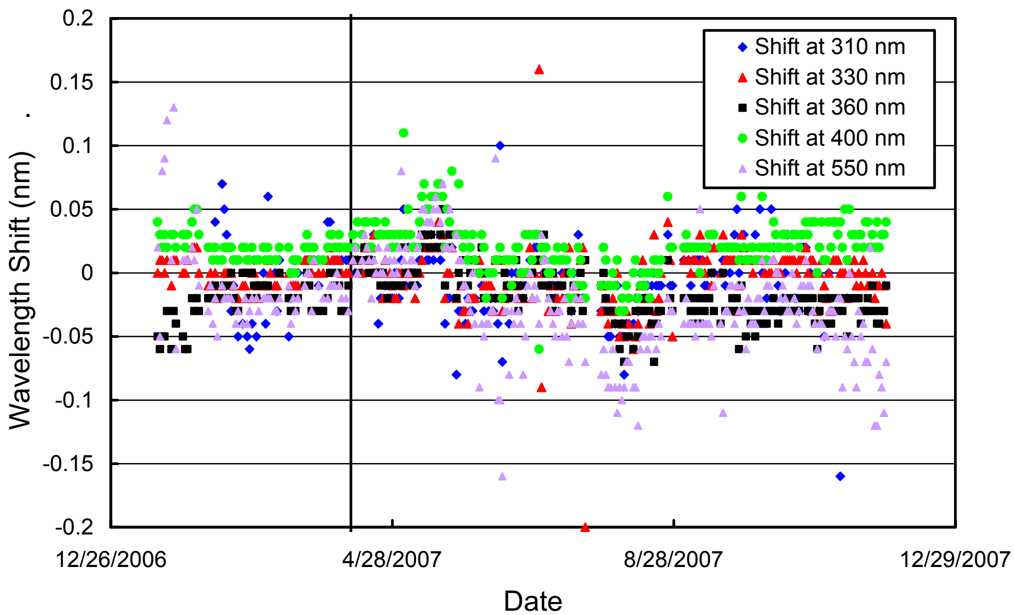

Figure 5.6.11. *Wavelength accuracy check of final data at four wavelengths in the UV and one in the visible by means of Fraunhofer-line correlation. The noontime measurement has been evaluated for each day of the reporting period when the Sun was above the horizon. The vertical line indicates the time when the monochromator non-linearity correction functions were changed.*

5.6.4. Missing Data

A total of 16506 scans are part of the Barrow Volume 16 dataset. 625 (3.2%) scans were superceded by calibration scans (absolute, response and wavelength scans). 12.5% of all possible solar scans were lost due to technical problems, which is a comparatively large amount. Table 5.6.2 gives a detailed overview of scans missing from the published data set.

Table 5.6.2. Missing solar scans of Barrow Volume 16 data.

Period	Number of scans	Reason
		Calibration scans
Throughout season	308	Response scans
Throughout season	235	Wavelength scans
Throughout season	82	Absolute scans
		Technical problems
01/20/07 - 03/21/07	563	Intermitted communication HRAD - computer / troubleshooting
03/25/07 - 04/08/07	344	Intermitted communication HRAD - computer / troubleshooting
04/09/07 - 04/12/07	116	Computer replacement and configuration
06/03/07 - 06/04/07	94	GPS time error / spectra overwritten
06/08/07	4	Software error for unknown reasons
07/21/07 - 07/27/07	580	Wavelength indicator jammed
08/08/07 - 08/10/07	171	Software error for unknown reasons
08/13/07	6	Software error for unknown reasons
08/23/07 - 08/25/07	149	Excessive monochromator temperature / large responsivity change
08/28/07 - 09/01/07	280	Excessive monochromator temperature / large responsivity change
09/15/07 - 09/17/07	147	HRAD error
		Other
Throughout season	28	Collector shaded by nearby obstacles (e.g., masts, stacks)
03/22/07 - 03/23/07	69	Collector covered with snow
05/10/07	26	Collector covered with snow
10/25/07	10	Collector covered with snow

5.6.5. 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. Data from the period 3/1/07 - 7/21/07 were used for this procedure. Data products were calculated from calibrated measurements (Section 4.3.2). Figure 5.6.12. shows a comparison of GUV-511 and SUV-100 erythemal irradiance based on final Volume 16 data. For solar zenith angles smaller than 75°, measurements of the GUV-511 instrument are on average 3% smaller than SUV-100 measurements. The bias between the two instruments depends somewhat on season: GUV-511 measurements tend to exceed SUV-100 data in early spring, when albedo is high, but are lower in summer and autumn, when albedo is low. The calculation of erythemal irradiance from GUV-511 raw data involves the use of modeled spectra. For these spectra, a surface albedo of 0.8 was assumed. This value is in agreement with typical albedo values prevailing at Barrow between October and May, but is too high for the months of June – September. Some of the seasonality in the bias between the two instruments is caused by the simplifications of the inversion procedure. Measurements of the GUV's 305 nm channel are close to the detection limit when SZA exceeds 75° and the total ozone column is large. The large noise in GUV data also affects the calculation of secondary data products such as erythemal irradiance. We advise data users to use SUV-100 rather than GUV-511 data when the SZA exceeds 75°.

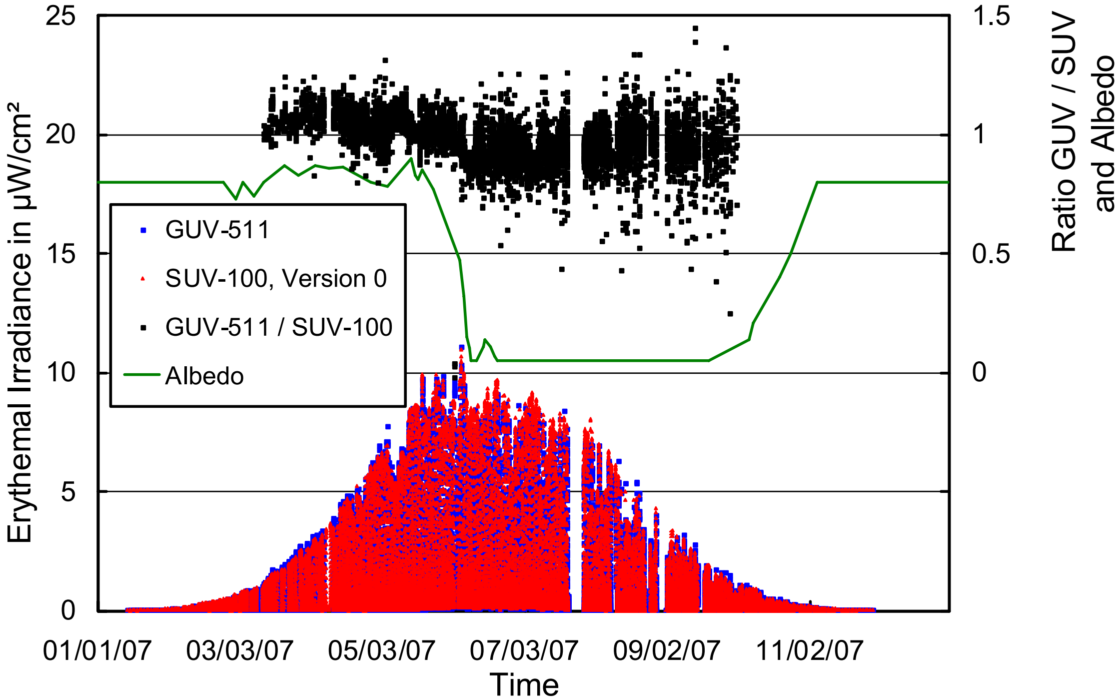

Figure 5.6.12. *Comparison of erythemal irradiance measured by the SUV-100 spectroradiometer and the GUV-511 radiometer. Data are based on "Version 0" (cosine-error uncorrected) data. The green curve indicates albedo and was taken from Version 2 data, available at www.biospherical.com/nsf/Version2.*

Figure 5.6.13 shows a comparison of total ozone measurements from the GUV-511, the Ozone Monitoring Instrument (OMI) on NASA's AURA satellite, the SUV-100 (Version 2 data), and a Dobson spectrophotometer operated by NOAA's Global Monitoring Division. GUV-511 ozone values were calculated as described in Section 4.3.3. GUV-511 data measured between April and September are 2% lower than OMI data, on average. In February in March, when the Sun is low and the ozone column large, GUV-511 tend to be low by 6-10%. Measurements of the instrument's 305 nm channel are close to the detection limit during these conditions. For SZAs larger than 75°, GUV-511 ozone data become unreliable and should not be used. SUV-100 ozone data exceed OMI measurements by 1.5% and Dobson measurements by 1.0%, on average. These discrepancies can partly be explained by the different ways ozone and temperatures profiles are treated by the different retrieval methods.

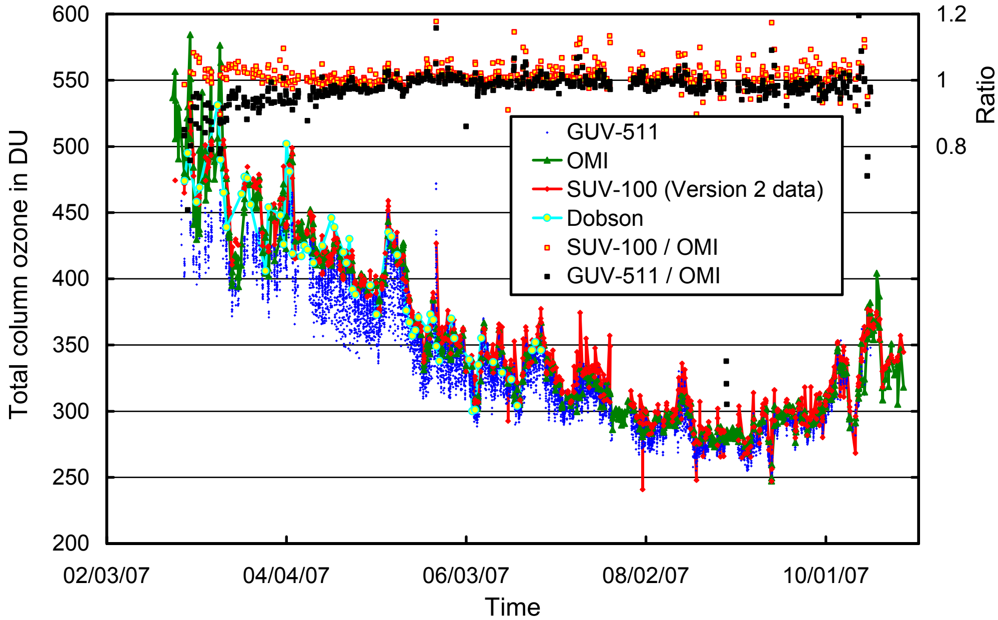

Figure 5.6.13. *Comparison of total column ozone measurements from GUV-511, OMI, SUV-100, and Dobson. GUV-511 measurements are plotted in 15 minute intervals. For calculating the ratios of SUV-100/OMI and GUV-511/OMI, only measurements concurrent with the OMI overpass were evaluated.*