5.6. Barrow, Alaska (3/9/04 – 6/5/05)

The 2004/05 season at Barrow is defined as the period between the site visits 3/2/04 – 3/10/04 and 6/4/05 – 6/7/05. Volume 14 solar data from the SUV-100 spectroradiometer comprise the period 3/9/04 – 5/13/05. Data from a GUV-511 multifilter instrument is available for the period 3/9/04 – 6/5/05. Season opening calibrations were performed on 3/7/04. Season closing calibrations could not be performed due to failure of the instrument's shutter two weeks prior to the site visit.

The following problems affected the performance of the instrument during the reporting period:

- **Insufficient temperature stabilization**
  The temperature inside the instrument enclosure frequently exceeded the set value of 28.5 °C by more than 5 °C. Likewise, the temperature of the monochromator was often more than 5 °C above the set point. In normal operation, the temperature of the monochromator is stable to within ±0.5 °C. Excess temperatures likely lead to failure of the shutter (see next item) and instability of the instrument's sensitivity. The excess temperature was caused by insufficient air-conditioning in the laboratory below the instrument.

- **Failure of shutter**
  During solar scans, the shutter located in the instrument's fore optics should be fully open. From 3/10/05 onward, the shutter did not open completely and the degree of openness varied from scan to scan. The problem was possibly caused by the excess temperature in the instrument's enclosure. When the frequency of solar scans was reduced on 3/26/05 from 4 scans per hour to 2 scans per hour, the problem disappeared, but reappeared on 5/13/05. From then until the end of the season, solar data cannot be used.

- **Computer failure**
  The system control computer's operating system became corrupted when the computer was power off on 9/6/04 without following proper shut-down procedures. The computer had to be shipped back to BSI for repair and was re-installed at Barrow on 9/30/04. There are no data between 9/6/04 and 9/30/04.

About 73% of the scheduled data scans are part of the published Volume 14 dataset. The relatively low yield is mostly caused by the failures of shutter and computer.

During the site visit in 2004, a GUV-511 multifilter radiometer was installed next to the SUV-100. The instrument helps in the quality control of SUV-100 data. It also provides measurements of several UV data products and total column ozone in near real-time. During the site visit in 2005, the mounting of the GUV-511 was upgraded to a more sturdy design. The PSP instrument was also replaced by an identical unit, which had been calibrated by Eppley Laboratories on 3/28/03.

5.6.1. Irradiance Calibration

The site irradiance standards of the reporting period were the lamps 200W009, M-762, and M-699. Lamp 200W017 was used as a traveling standard during the 2004 site visit. All four lamps had been calibrated by Optronic Laboratories in March 2001. During the 2005 site visit, lamp 200W028, which also serves as site standard at San Diego was used. This lamp was calibrated on 4/26/05 by BSI against lamps 200W017 and M-763. The latter lamp was calibrated by Optronic Laboratories in March 2001.

Figure 5.6.1 shows a comparison of lamps 200W009, M-762, M-699 and 200W017 at the beginning of the period (3/7/04). All lamps agreed with each other to within ±1.5% in the UV and ±1.0% in the visible. These differences are well within the uncertainties of calibration standards. It was not possible to perform calibration scans at the end of Volume 14 due to the shutter failure. Instead, Figure 5.6.2 shows a comparison of lamps 200W009, M-762, M-699 and 200W028 performed on 6/6/05 at the beginning of Volume 15. All lamps agreed on the ±1.5% level. In addition to scans conducted during site visits, the three site standard were compared against each other on 7/2/04 and agreed to within ±1.0%.

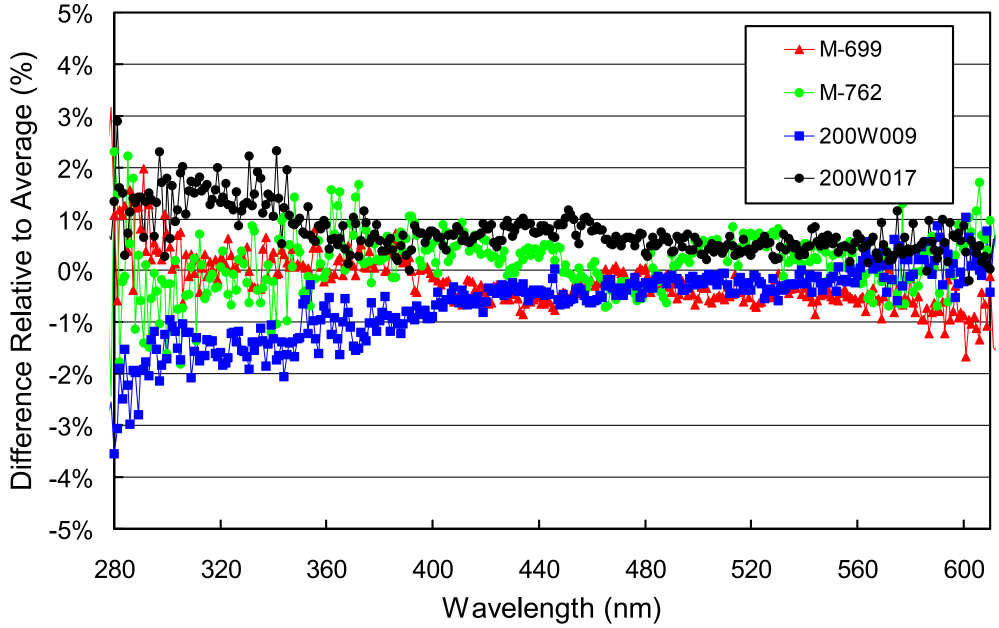

Figure 5.6.1. *Comparison of lamps 200W009, M-762, M-699, and 200W017 at the beginning of the Volume 14 period.*

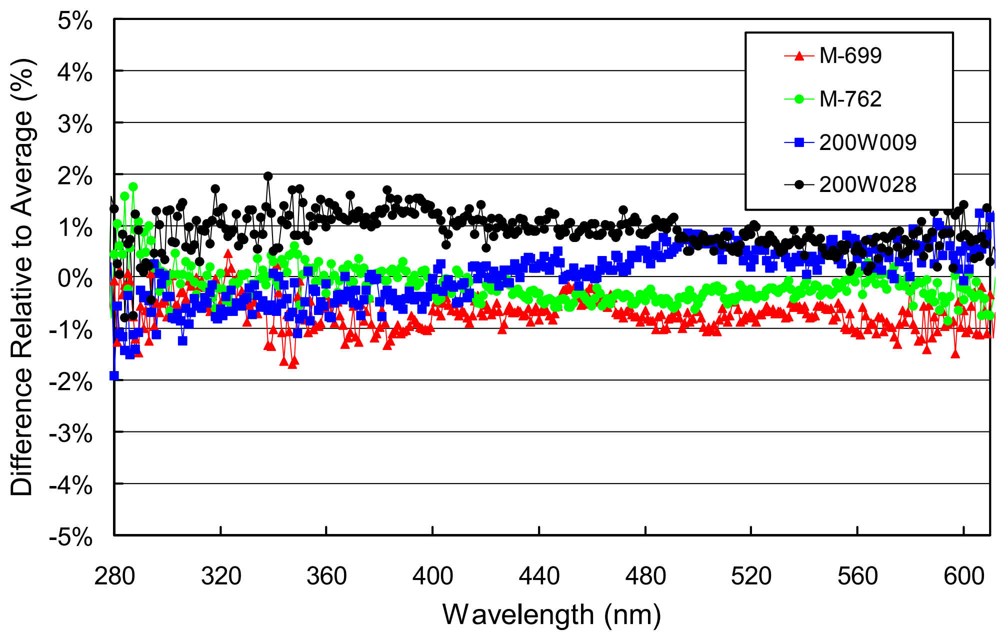

Figure 5.6.2. *Comparison of lamps 200W009, M-762, M-699, and 200W028 at the beginning of Volume 15.*

5.6.2. 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 this 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 monochromator throughput and PMT sensitivity can be detected.

Figure 5.6.3 shows changes in TSI readings and PMT currents at 300 and 400 nm, derived from the daily response scans of the period 3/9/04 – 6/4/05. TSI measurements indicate that the internal lamp became brighter by about 2% between March and October 2004, before becoming dimmer again. PMT currents are generally tracking the TSI measurement.. Between 5/13/04 and 9/8/05, PMT currents show a relatively large day-to-day variability. The highest departure from the general pattern occurred on 7/25/04 when the PMT current at 300 nm was 10% below the value measured on 7/22/04. These instabilities were caused by insufficient temperature stabilization of the instrument and were related to insufficient air-conditioning in the laboratory below the instrument. PMT currents anti-correlate with the temperature of the monochromator, which is also indicated in Figure 5.6.3. On 7/25/04, the temperature rose to 38.5 °C, which is 5.5 °C above the set point.

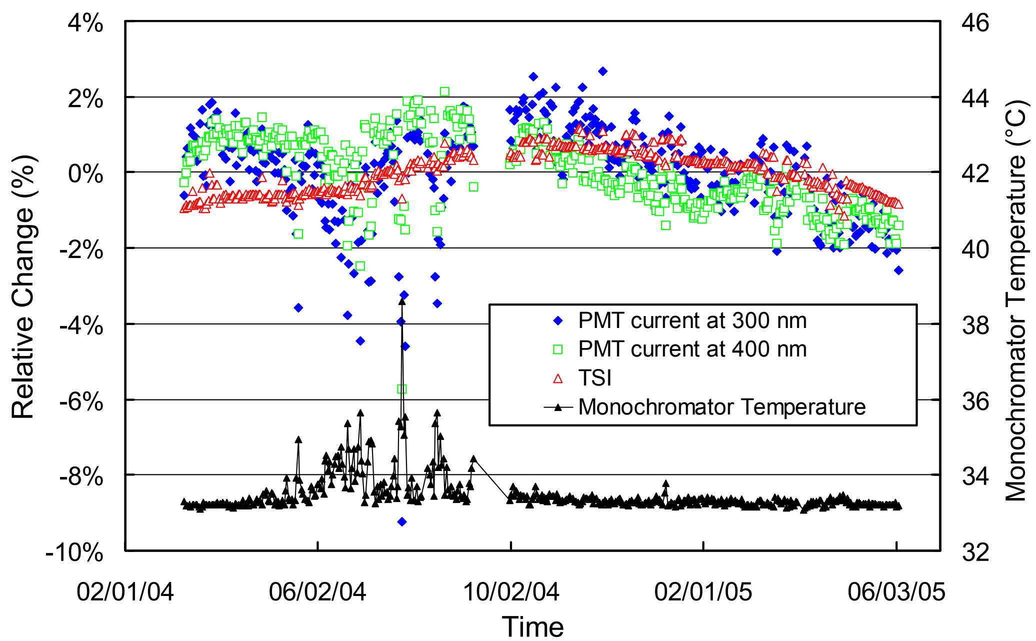

Figure 5.6.3. *Left axis: Time-series of PMT current at 300 and 400 nm, and TSI signal extracted from measurements of the internal irradiance standard at Barrow between* 3/9/04 – 6/4/05. *All data sets are normalized to the average. Right axis: Monochromator temperature.*

If the temperatures within the instrument's enclosure had been constantly high within a given day, solar data would not be affected since application of the daily response scan corrects for temperature departures during solar measurements. Unfortunately, temperatures during solar and response scans were often different and this caused systematic errors. These errors were quantified by comparing measurements of the SUV-100 with measurements of the collocated GUV-511 multifilter radiometer (see also Section 5.6.5). Figure 5.6.4. compares the ratio GUV-511 / SUV-100 at 340 nm with monochromator temperature. When the monochromator temperature was stable at 33±0.5 °C, GUV-511 and SUV-100 measurements typically agreed to within ±5%. When the temperature rose to 39.8 °C on 7/25/05, GUV-511 readings were 15% higher than SUV-100 measurements. The GUV-511 radiometer is not affected by the temperature instabilities. It can therefore be concluded that the SUV-100 measured 15% low on that particular day.

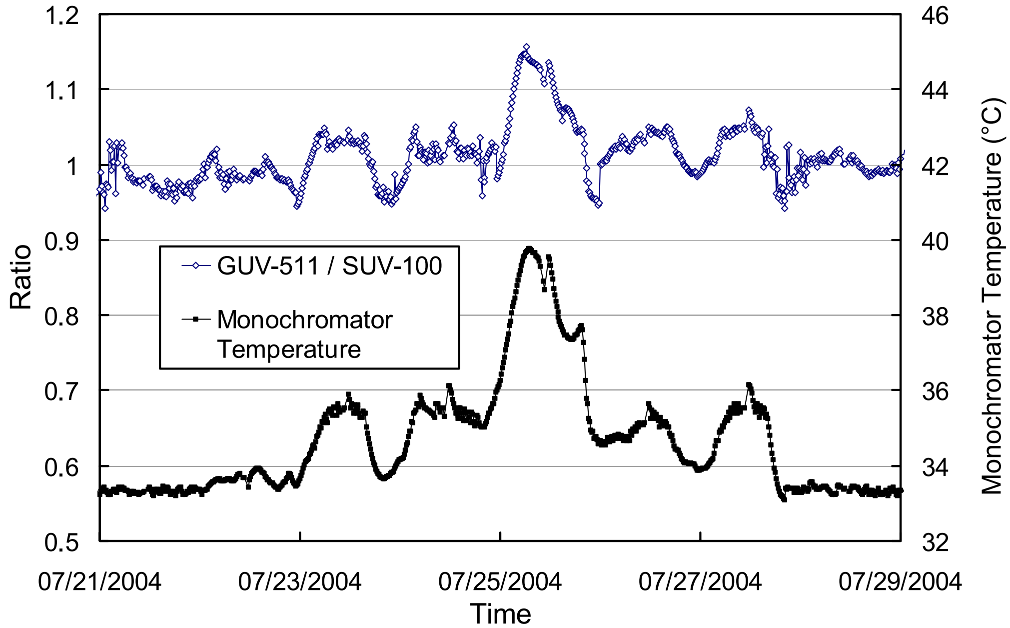

Figure 5.6.4. *Left axis: Ratio of GUV-511 measurements of the 340-nm channel to SUV-100 measurements weighted with the spectral response function of the 340-nm GUV-511 channel. Right axis: Monochromator temperature.*

Monochromator temperature was noticeable instable during the periods 4/24/04 – 10/26/04 and 4/29/05 – 4/30/05. Temperature variations by more than ±1 °C were observed during the periods: 5/20/04 14:00 – 17:00, 6/6/04 – 7/6/04, 7/23/04 – 7/27/04, 4/14/04 – 8/18/04, and 4/29/05 – 4/30/05. The correlation between the ratio GUV-511 / SUV-100 and temperature is not as well defined in all periods as for the period presented in Figure 5.6.4. Corrections for the temperature effect are therefore difficult to determine and were not applied. The possible range of systematic errors in SUV-100 measurements at 340 nm are summarized in Table 5.6.1. Errors at other wavelengths may be somewhat smaller or larger, but this cannot be easily quantified. Data from the periods indicated in Table 5.6.1 should be used with caution.

Table 5.6.1. Periods affected by systematic errors in SUV-100 data.

Period	Systematic error at 340 nm	Reason
05/17/04 13:00 - 05/20/04 16:00	SUV low by up to 14%.	High temperature
06/20/04 19:45 - 06/21/04 00:45	SUV low by up to 14%	High temperature
06/26/04 12:00 - 06/26/04 19:00	SUV low by up to 20%.	Unknown
06/28/04 03:30 - 06/28/04 12:30	SUV low by up to 9%	High temperature
07/04/04 23:30 - 07/05/04 09:00	SUV low by up to 9%.	High temperature
07/07/04 05:00 - 07/07/04 14:30	SUV low by up to 11%.	Unknown
07/24/04 23:15 - 07/25/04 23:45	SUV low by up to 15%.	High temperature
08/13/04 11:45 - 08/19/04 00:00	SUV low by up to 15%.	High temperature
04/29/05 20:00 - 04/30/05 09:00	SUV low by up to 16%.	High temperature

Absolute calibrations performed with 200-Watt standards throughout the reporting period showed somewhat larger changes in instrument sensitivity than those indicated in Figure 5.6.3. These changes may be caused by contamination inside the fore-optics, which cannot be detected with scans of the internal reference lamp. To account for these changes, the reporting period was broken into six different periods, indicated in Table 5.6.2, and a different irradiance spectrum was assigned to each period. The spectra for Periods P1B and P2B were interpolated. Figure 5.6.5 shows ratios of all spectra to the spectrum of the first period.

Table 5.6.2: Calibration periods of Barrow Volume 14 data.

Period name	Period range	Number of Absolute scans	Remarks
P1	03/06/04 - 04/12/04	9	
P1B	04/13/04 - 04/20/04	0	Interpolated from P1, P2
P2	04/21/04 - 05/10/04	3	
P2B	05/11/04 - 06/03/04	0	Interpolated from P2, P3
P3	06/04/04 - 02/04/05	18	
P4	02/05/05 - 06/05/05	8	

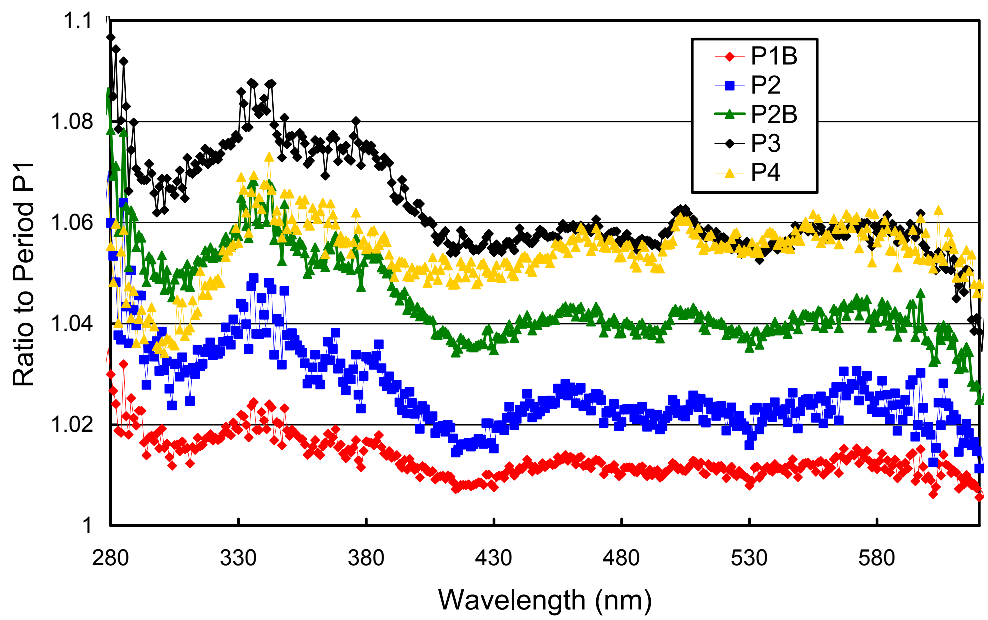

Figure 5.6.5. *Ratios of spectral irradiance values assigned to the internal reference lamp during the Periods P1B –P4 to Period P1.*

Figure 5.6.6 presents ratios of standard deviation and average spectra, calculated from the individual absolute scans of each period. These ratios are useful for estimating the variability of calibrations in each period. The variability is typically less than 1.5% for wavelengths in the UV-A and visible, and is 2.5% below 300 nm, indicating good consistency of calibrations in all periods.

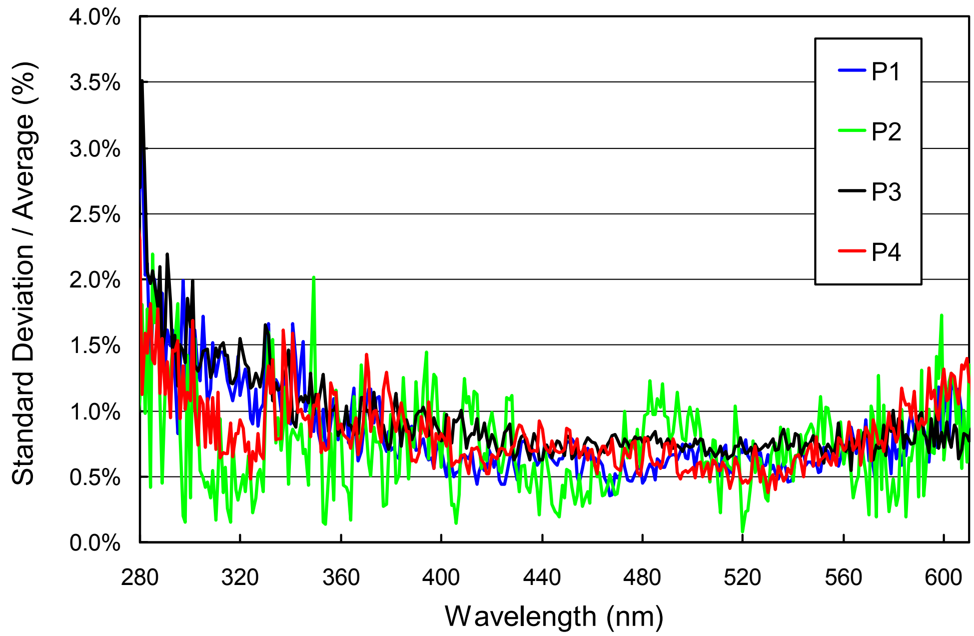

Figure 5.6.6. *Ratio of standard deviation and average spectra calculated from absolute calibration scans.*

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. 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 5.6.7 shows the differences in the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 471 scans were evaluated. For 97.2% (99.2%) of the days, 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 two pairs of wavelength scans were larger than ±0.1 nm, and were related to operator intervention. Data was corrected 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 Fraunhofer-line correlation method described in Section 4.2.2.2. Figure 5.6.8 shows the resulting correction function.

After all data was corrected by applying this function, the wavelength accuracy of noon-time spectra was confirmed with the Fraunhofer-line correlation method. The results for four UV wavelengths are shown in Figure 5.6.9. For wavelengths between 320 and 400 nm, residual shifts are typically smaller than ±0.1 nm. Residual shifts at 310 nm are larger, in particular between October and March, when irradiance levels are low. The wavelength stability is not worse during this time; yet the validation is less precise. Wavelengths accuracy is only little affected by the monochromator’s temperature variations. One exception is the periods between 7/23/04 and 7/25/04, when the residual shift drops to approximately -0.07 nm.

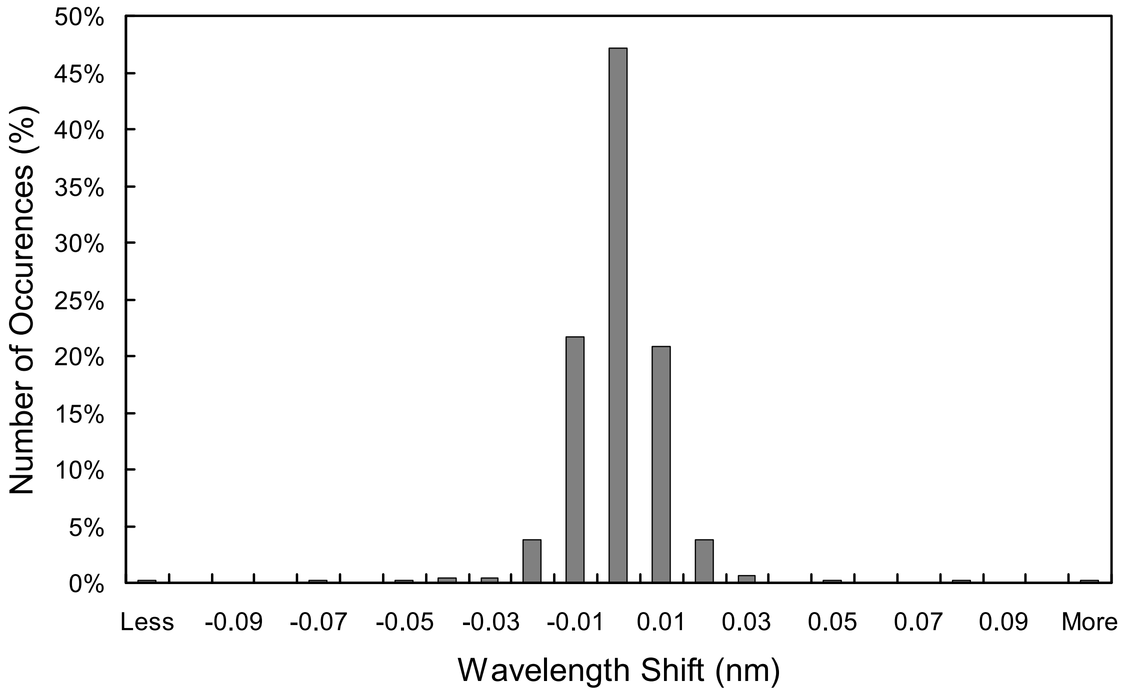

Figure 5.6.7. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. Thus the 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more" means shifts larger than 0.105 nm.*

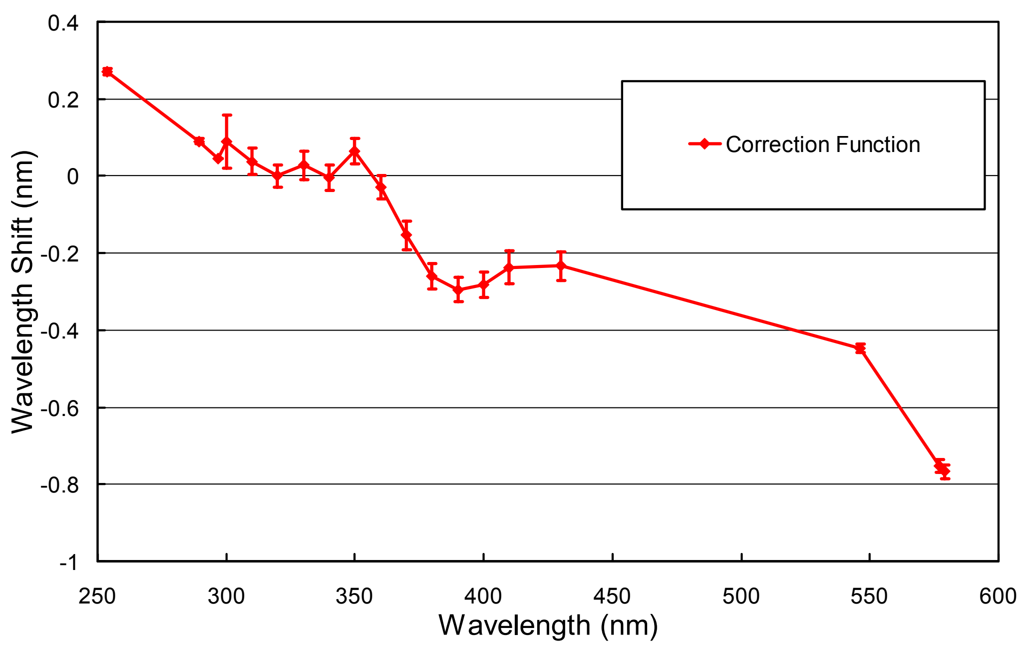

Figure 5.6.8. *Monochromator non-linearity correction functions for Volume 14 Barrow.*

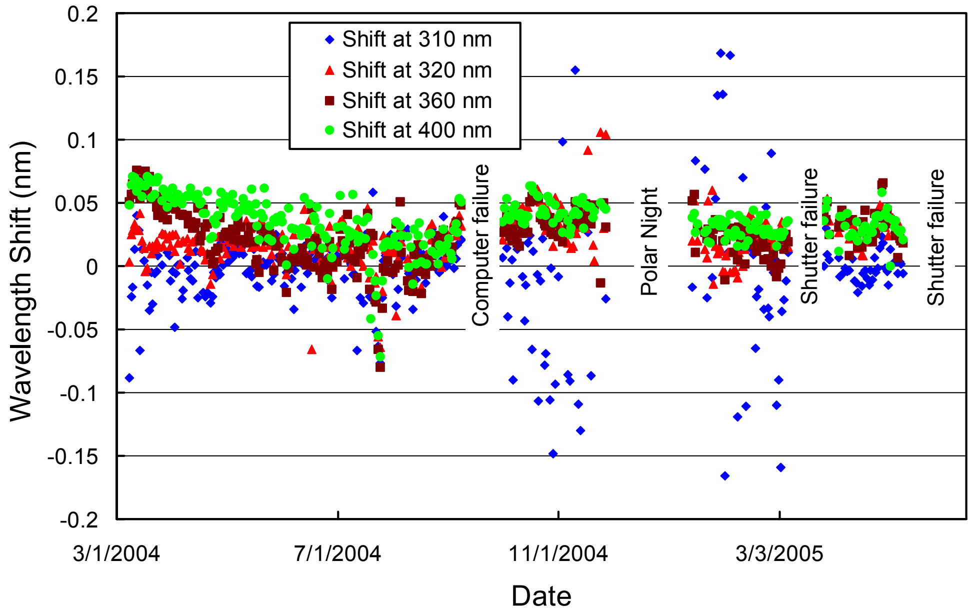

Figure 5.6.9. *Wavelength accuracy check of final data at four wavelengths in the UV by means of Fraunhofer-line correlation. The noontime measurement has been evaluated for each day of the reporting period when the Sun was above the horizon. No data are available for periods affected by computer and shutter failures, and during Polar Night.*

Although data from the external mercury scans do not have a direct influence on data products, they are an important part of instrument characterization. Figure 5.6.10 illustrates measurements of the 296.73 nm mercury line of internal and external mercury scans collected during the 2004 site visits. No data from the 2005 site visit are available due to the problem with the shutter. The internal scan has a bandwidth of about 0.74 nm FWHM; the bandwidth of the external scan is 1.03 nm FWHM. The external scan is well centered at the nominal wavelength of 296.63 nm. The internal scan is shifted by approximately 0.06 nm. External scans have the same light path as solar measurements and represent the monochromator bandpass at 296.73 nm.

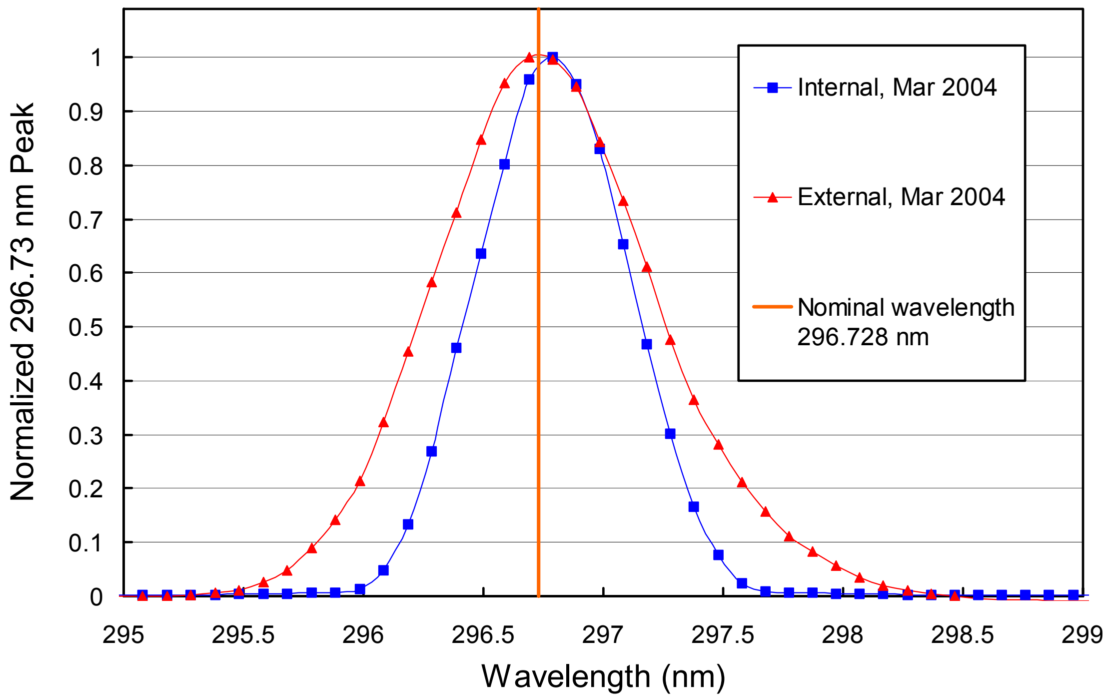

Figure 5.6.10. *The 296.73 mercury line as registered by the PMT from external and internal sources at the start of the reporting period. The wavelength scale is the same as applied for solar measurements.*

5.6.4. Missing Data

A total of 19356 scans are part of the published Barrow Volume 14 dataset. These are 73% of all possible solar scans. This is a comparatively low yield, which can be explained by the failures of computer and shutter. The total percentage of scans missing due to technical problems is 22%. From 3/26/05 onward, the system's scan rate was reduced from 4 scans per hour to 2 scans per hour, which lead to a loss of 1722 scans, or 6.5% of all scans scheduled. Of the remaining missing scans, 0.6%, 1.2%, and 1.4% were superseded by absolute, wavelength, and response scans, respectively. Table 5.6.3 gives a more detailed overview of scans lost due to technical problems.

Table 5.6.3. Missing solar scans in Barrow Volume 14 data.

Reason	Period	Number of scans
Measured values abnormally high	07/03/04	15
Full disk drive	08/07/04 – 08/09/04	122
Computer failure	09/09/04 – 09/30/04	1177
Snow on SUV-100 collector	11/02/04	27
Snow on SUV-100 collector	02/17/05 – 02/20/05	102
Shutter failure	03/10/05 – 03/26/05	578
Reduced sampling rate due to shutter failure	03/26/05 – 05/13/05	1722
Communication problem PC – A/D converter (HRAD)	04/01/05 – 04/04/05	205
Snow on SUV-100 collector	04/06/05 – 04/07/05	33
Shutter failure	05/13/05 – 06/04/05	2046
Operator interventions, operating system updates	various	30

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 products were calculated from the calibrated measurements (Section 4.3.2). Figure 5.6.11. shows a comparison of GUV-511 and SUV-100 erythemal irradiance based on final Volume 14 data. For solar zenith angles smaller than 75°, measurements of the GUV-511 instrument between March and May are on average 3±5% higher than SUV-100 data. Between June and September, GUV-511 data are 7±10% lower. The larger variability of the ratio during fall can be explained by the larger change in cloudiness. 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 clearly too high for the months of June – September. The 7% bias between GUV-511 and SUV-100 data during fall is partly caused by the incorrect albedo used in the inversion procedure. We advise data users to use SUV-100 rather than GUV-511 data when possible, in particular for low-Sun conditions.

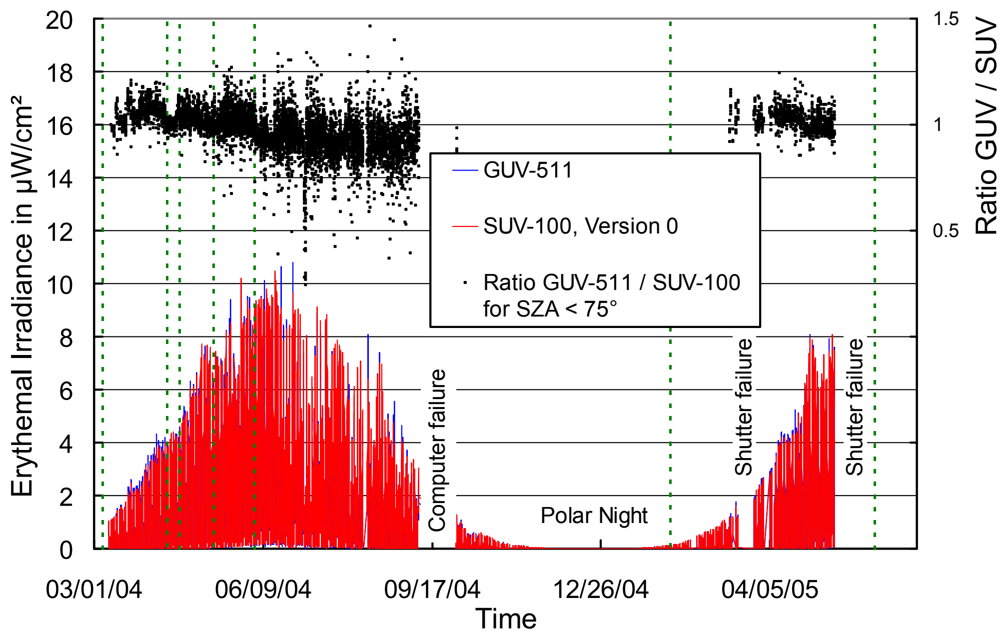

Figure 5.6.11. *Comparison of erythemal irradiance measured by the SUV-100 spectroradiometer and the GUV-511 radiometer. All data is based on "Version 0" (cosine-error uncorrected) data.*

Figure 5.6.12 shows a comparison of total ozone measurements from the GUV-511 and NASA/TOMS Earth Probe satellite (Version 8). GUV-511 ozone values were calculated as described in Section 4.3.3. TOMS ozone values are on average 1% smaller than GUV-511 data. For SZA larger than 80°, GUV-541 data become unreliable and should not be used.

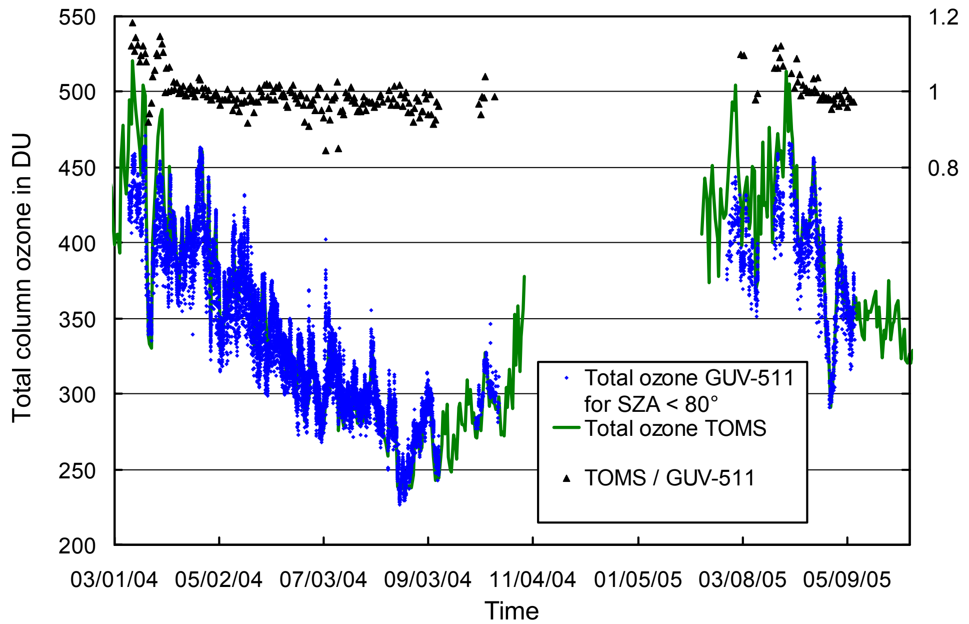

Figure 5.6.12. *Comparison of total column ozone measurements from GUV-511 and NASA/TOMS Earth Probe satellite. GUV-511 measurements are plotted in 15 minute intervals. For calculating the ratio of both data sets, only GUV-511 measurements concurrent with the TOMS overpass data were evaluated.*