5.6. Barrow, Alaska (1/13/08– 07/12/09)

This section describes quality control of solar data recorded at Barrow between 1/14/08 and 7/12/09. There was no site visit by BSI personnel during this period and the level of operational support at Barrow was less than ideal. For example, only nine absolute scans were performed between August 2008 and July 2009 and the instrument's collector was only cleaned occasionally during this period. The instrument's response lamp became unstable in July 2008 and was not be replaced before March 2009. As a consequence, scans of the lamp could not be used to track and adjust changes of the system's sensitivity on a daily bases as it is done usually. In addition, the instrument's shutter started to become "sticky" in April 2008 when it did not fully open during solar scans. The problem was mitigated by changing the system's duty cycle from four scans per hour to two scans per hour. The shutter was repaired on 4/16/09, however, the reduced duty cycle was kept as a precautionary measure.

Variations of the spectroradiometer's responsivity was checked, and adjusted if necessary, using data of the site's GUV-511 multifilter radiometer. The calibration of this instrument proved to be very stable during this period. For most days, the uncertainty of published SUV-100 data is only slightly (e.g., <5%) larger compared to that of previous seasons. Periods with increased uncertainty are listed in Table 5.6.1. A total of 17128 SUV scans are part of the Barrow Volume 18 dataset.

5.6.1. Irradiance Calibration

The site irradiance standards of the reporting period were the lamps M-699, 200W009, and 200W042.

Lamp 200W042 was calibrated in June 2007 at BSI with four 1000-Watt FEL lamps provided by the Central UV Calibration Facility (CUCF) at Boulder. This calibration procedure was complicated by the fact that the irradiance scale of the four FEL lamps refers to the detector-based scale of the National Institute of Standards and Technology established in 2000 (NIST2000; *Yoon et al*., 2002), whereas all solar data of the NSF UVSIMN refer to the source-based NIST scale from 1990 (NIST1990, *Walker et al*., 1987). The NIST2000 scale is about 1.3% larger than the NIST1990 scale. Data of certificates issued by CUCF were converted to the NIST1990 scale before the calibration was transferred to the site standard.

Lamps M-699 and 200W009 were originally calibrated by Optronic Laboratories (OL) in March 2001 and this calibration was used for solar calibrations of the Volume 16 period (2006-2007). Both lamps were brought to San Diego in 2007 and recalibrated against lamps 200W028 and 200W022. (Lamp 200W028 is the San Diego site standard; lamp 200W022 is BSI's long-term standard, which preserves the OL scale from March 2001.) The new irradiance table established for lamp M-699 is 0.8% larger than the original table issued by OL; the new table for 200W009 is 2.3% larger. The new tables were used for calibrating solar measurements of the reporting period.

Figures 5.6.1 shows a comparison of the three site standards performed on 4/17/09. The calibrations of the lamps agree with each other to within ±1%. This confirms that the irradiance scale derived from the CUCF lamps (represented by lamp 200W042) is consistent to that of the 2001 OL scale (preserved by lamps M-699 and 200W009).

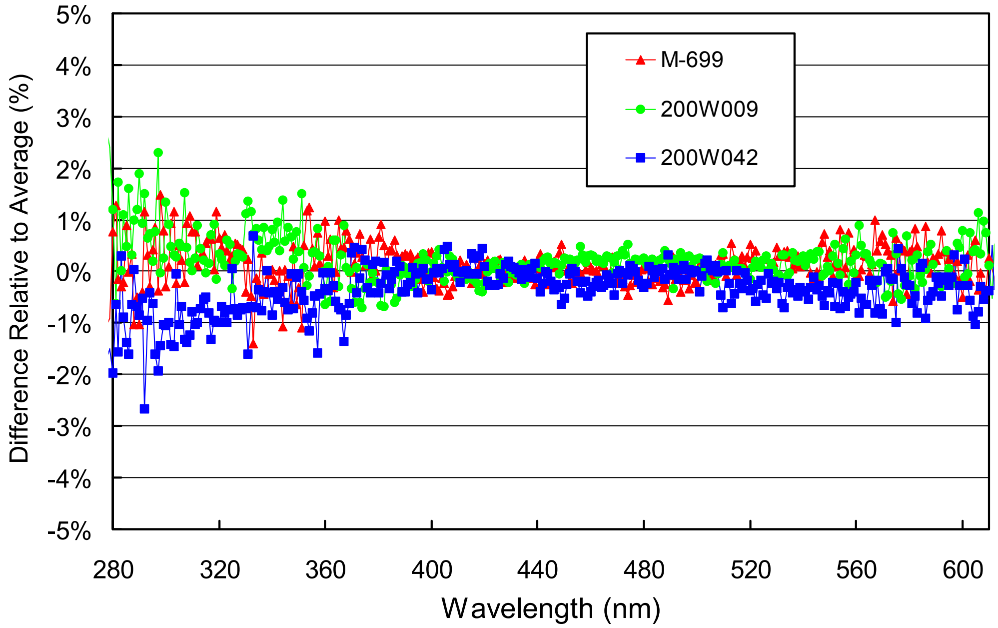

Figure 5.6.1. *Comparison of lamps 200W009, M-699 and 200W042 on 4/17/09.*

5.6.2. Instrument Stability

The radiometric stability of the SUV-100 spectroradiometer over time is usually monitored with calibrations utilizing site irradiance standards and daily response scans of the internal irradiance reference lamp. This procedure had to be modified for data of the reporting period due to the scarcity of absolute scans and the instability of the response lamp (Figure 5.6.2). Specifically, solar data of the period 6/28/08 - 12/31/08 were "paired" with the response scan performed on 7/1/08. The irradiance assigned to this response scan was calculated based on an absolute scan executed on the same day. Using this procedure, the system was "let to believe" that the response lamp was stable during the second part of 2008, i.e., that it produced the same output as measured on 7/1/08 on all days of this period. The procedure is only adequate if the system's responsivity does not change appreciably. By comparing SUV-100 and GUV-511 (Figure 5.6.4), it was determined that the SUV's responsivity varied by about 5% during the second part of the 2008. GUV data were used to adjust the SUV's calibration accordingly. Most data of the affected period have an additional uncertainty of about 3% as some variation in the ratio of GUV and SUV may have been caused by sensitivity changes of the GUV, for example by a soiled collector.

Solar measurements of the period of 1/1/09 - 4/16/09 were calibrated in a similar way by pairing solar data scans with the response scan performed on 3/13/09. The irradiance assigned to this response scan was calculated based on two absolute scans executed on 3/13/09. The comparison with the GUV indicated a 4% step-change in the ratio of the two instruments, independent of wavelength, occurring on 3/13/09. We assumed that this change was caused by variations in the SUV's sensitivity. To correct for this drift, SUV data measured between 1/1/09 and 3/12/09 were scaled downward by 4% (Table 5.6.1).

Figure 5.6.2 shows changes in TSI readings and PMT currents at 300 and 400 nm that were derived from the daily response scans. TSI measurements increase steadily by about 5% between January and July 2008, indicating gradually brightening of the internal lamp. Thereafter, TSI measurements fluctuate within a range of about ±10% due to the lamp's instability. Measurements taken after 3/20/09 with the new response lamp show a gradual and predictable increase. In general, PMT currents track measurements of the TSI well, indicating good stability of monochromator and PMT during the reporting period. One exceptions is the drop in the PMT measurements on 5/15/08, following overheating of the system caused by high laboratory temperatures. Another exception is the increase in PMT measurements following the shutter repair on 4/16/09.

A total of eleven calibration functions were applied to solar data of the reporting period. Figure 5.6.3 shows the ratio of those functions relative to the function of Period P1 (1/1/08 - 2/29/08). More details are provided in Table 5.6.1, which also indicates periods when calibration files were scaled to force SUV measurements to agree with GUV data.

The ratio of final GUV and SUV data at 340 nm is shown in Figure 5.6.4. Data of both instruments are typically consistent at the ±5% level.

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 drifts of the SUV-100 within calibration periods, infrequent cleaning of the SUV and GUV collectors, and a possible long-term change 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.

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/). The ratio of measured and modeled data was generally within the range observed in past years.

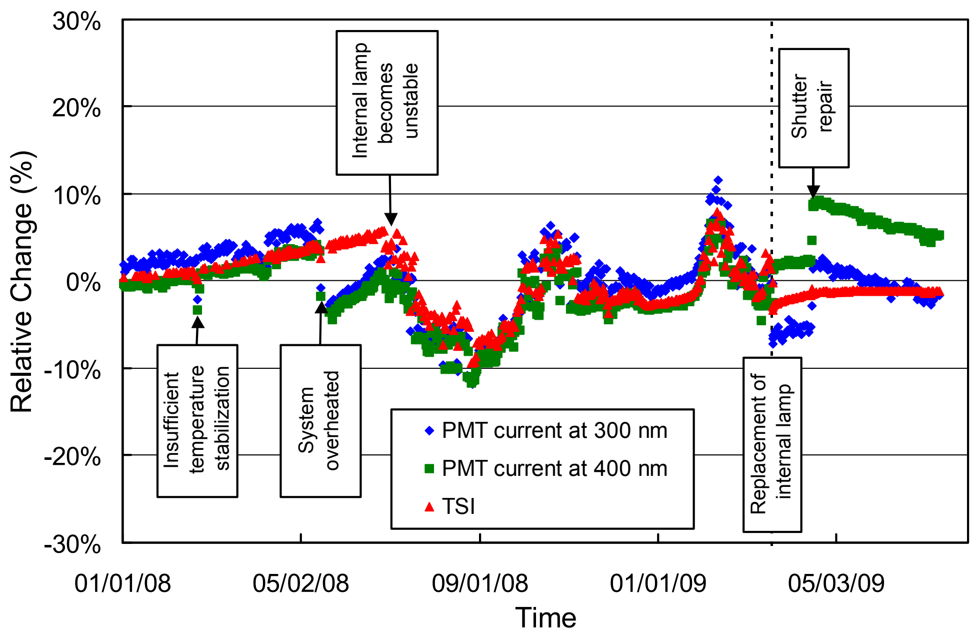

Figure 5.6.2. *Time-series of PMT current at 300 and 400 nm, and TSI signal extracted from measurements of the internal irradiance standard at Barrow between 1/1/08 – 7/14/09. All data sets are normalized to their average.*

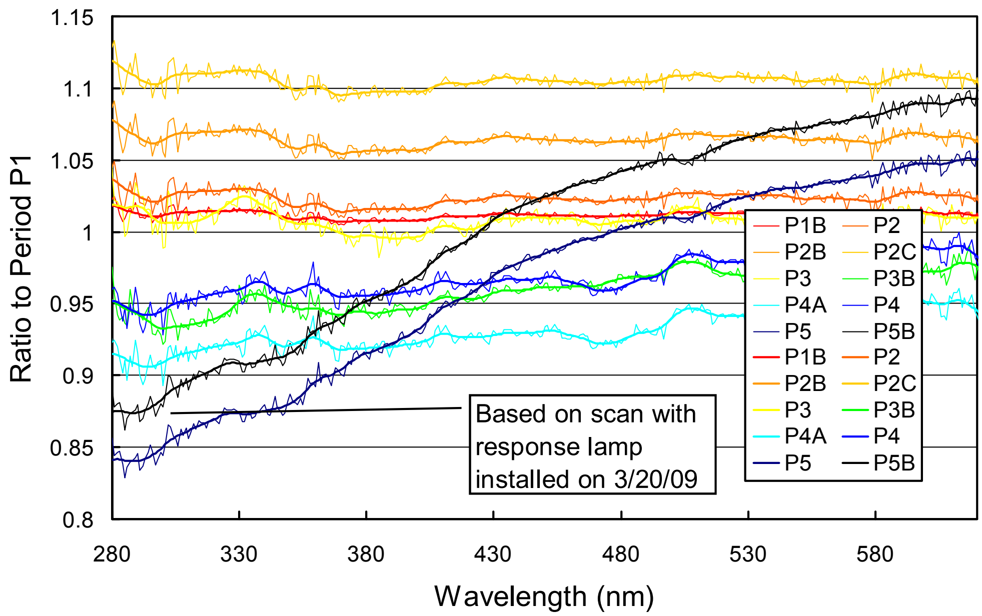

Figure 5.6.3. *Ratios of spectral irradiance functions assigned to the internal reference lamp during the Periods P1B – P5B, relative to Period P1. Functions were smoothed with an approximating spline before calibrating solar data.*

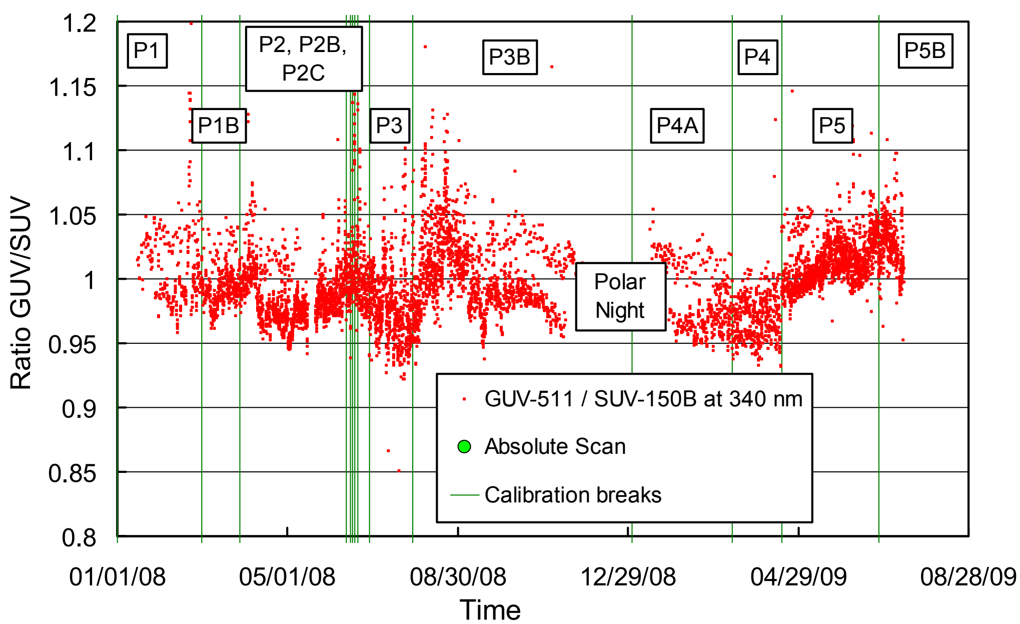

Figure 5.6.4. *Ratio of GUV-511 measurements of the 340-nm channel to SUV-100 measurements. The latter were weighted with the spectral response function of the 340-nm GUV-511 channel. Only data for SZA<85° are plotted. Times of absolute scans and calibration breaks are also indicated.*

Table 5.6.1: Calibration periods of Barrow Volume 18 data.

Period	Period range	Scans*	Remarks	Possible Bias+
P1	01/01/08-02/29/08	2		generally 0%, - 3% on 02/19/08 and -5% on 02/20/08 due to monochromator overheating
P1B	03/01/08-03/27/08	0	Average of P1 and P2	±1.5%
P2	03/28/08-06/11/08 and 06/15/08 and 06/19/08-06/27/08	4	Some variation due to infrequent collector cleaning	generally ±3%, up to -8% on 04/06/08 due to monochromator overheating, up to -10% on 06/15/08, up to -10% on 06/21/08,
P2B	06/12/08-06/14/08 and 06/16/08-06/17/08	0	P2, scaled upward by 4%	generally ±2%, up to -10% on 06/17/08
P2C	06/18/08-06/19/08	0	P2, scaled upward by 8%	±1.5%
P3	06/28/08-07/28/08	1		generally +2%±2%, up to -10% on 07/23/08
P3B	07/29/08-12/31/08	2	Calibration based on 200-W item of response scan only	generally ±3%, up to -10% on 08/06/08, 08/11/08, 08/20/08,
P4A	01/01/09-03/12/09	0	P4, scaled downward by 4%	+2.5%±1%
P4	03/13/09-04/16/09	2		+2.5%±1%
P5	04/17/09-06/24/09	3		generally ±2.5%, -3% to -10% on 05/31/09 -5% to -9% on 06/04/09 -5% to -10% on 06/06/09, 06/07/09 up to -5% on 07/11/09, 06/07/09
P5B	06/25/09-07/31/09	0	P5, scaled upward by 4%	-2.5%

* Number of absolute scans performed in given period.

+ Indicated by GUV/SUV comparison. Positive values suggest that SUV-100 data are too high.

Figure 5.6.5 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 1.5% in the UV-A and visible for all periods but Period P4. The calculation for this period is based on two absolute scans only.

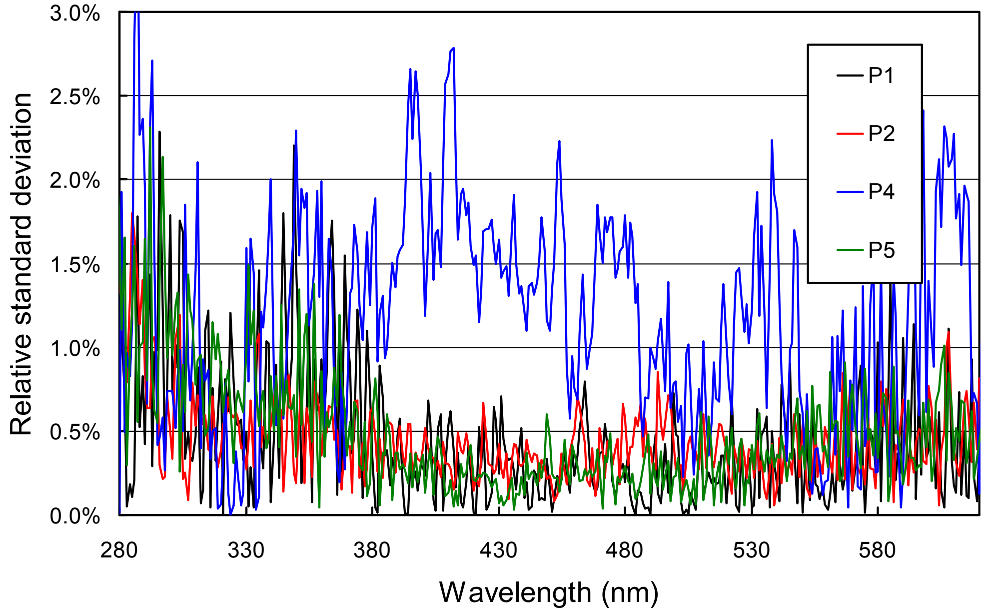

Figure 5.6.5. *Ratio of standard deviation and average spectra calculated from absolute calibration scans.*

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 5.6.6 shows the differences in the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 590 pairs were evaluated. In 95% (99%) 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. Only for one pair was the difference larger than ±0.1 nm.

Three functions for correcting the non-linearity of the monochromator's wavelength drive were implemented and are shown in Figure 5.6.7. 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 5.6.8. Residual shifts in the UV are typically smaller than ±0.05 nm. Wavelengths accuracy is only little affected by the monochromator's temperature variations.

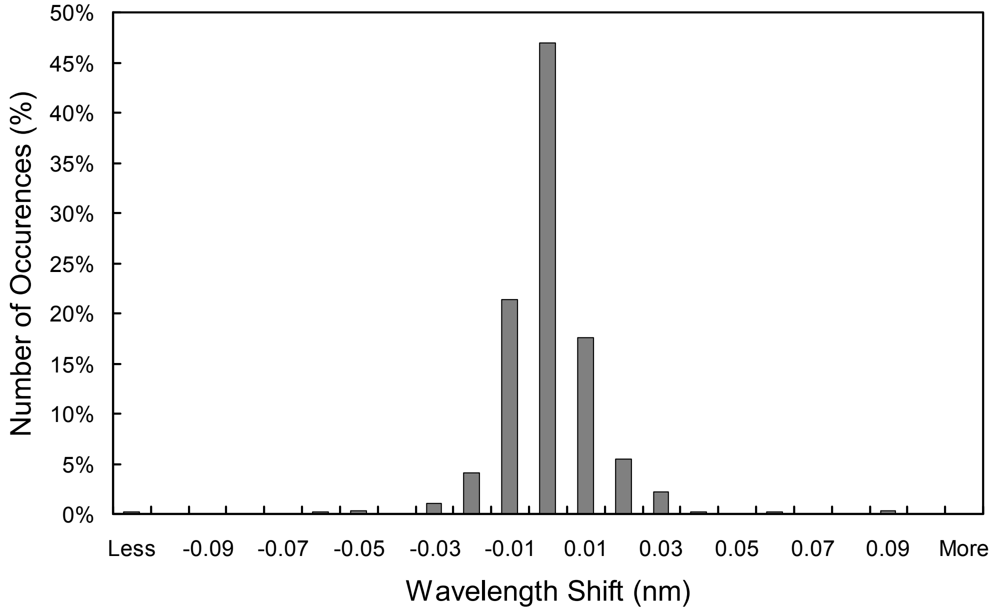

Figure 5.6.6. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. Thus the 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more" means shifts larger than 0.105 nm.*

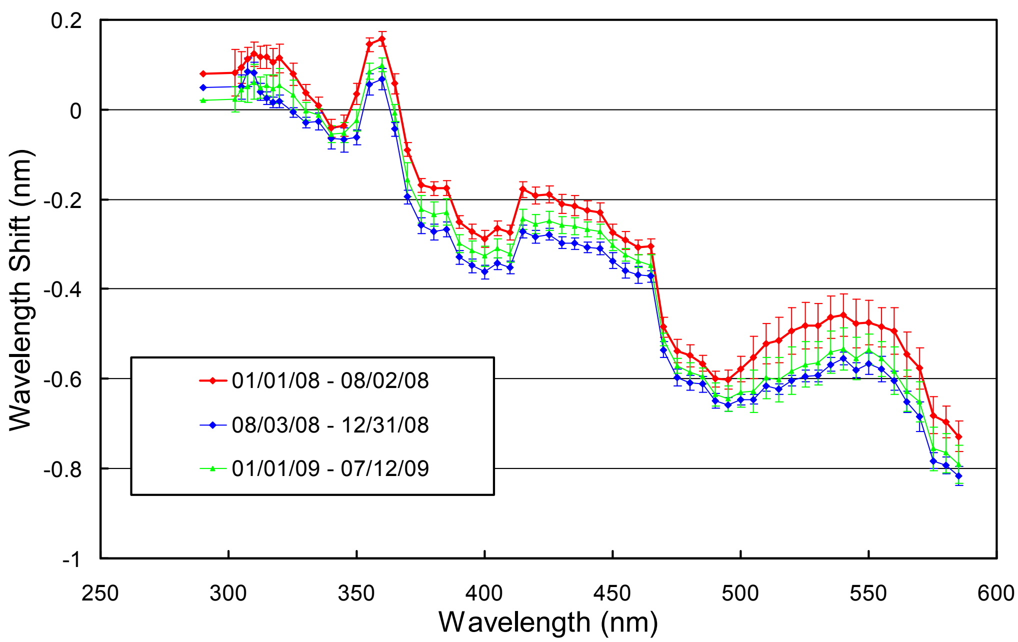

Figure 5.6.7. *Monochromator non-linearity correction functions for Barrow Volume 18.*

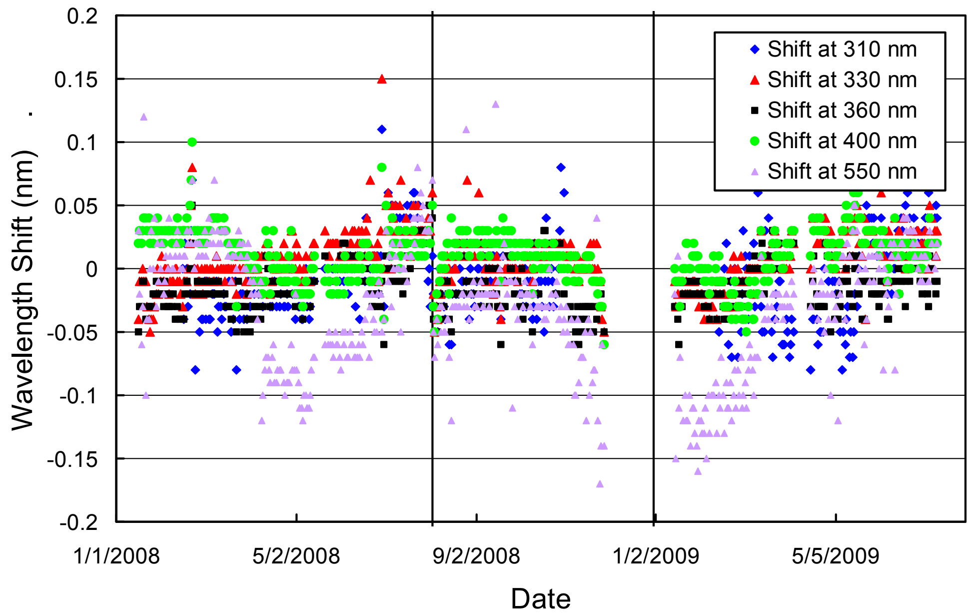

Figure 5.6.8. *Wavelength accuracy check of final data at four wavelengths in the UV and one in the visible by means of Fraunhofer-line correlation. The noontime measurement has been evaluated for each day of the reporting period when the Sun was above the horizon. The vertical line indicates the time when the monochromator non-linearity correction functions were changed.*

5.6.4. Missing Data

A total of 17128 scans are part of the Barrow Volume 18 dataset. In April 2008, the instrument's duty cycle was changed from 4 scans per hour to 2 scans per hour to allow the system's shutter to cool between Measurements. 888 scans (4.7%) were lost due to technical problems, not counting scans missing due the reduced duty cycle. 985 (5.2%) solar scans were superceded by calibration scans (absolute, response and wavelength scans). Table 5.6.2 gives a detailed overview of scans missing from the data set. There are no GUV data for 8/8/07, 10/15/07, 3/7/08, 5/25/08, 6/25/08, 9/9/08, and 3/21/09.

Table 5.6.2. Missing solar scans of Barrow Volume 18 data.

Period	Number of scans	Reason
		Calibration scans
Throughout season	528	Response scans
Throughout season	381	Wavelength scans
Throughout season	80	Absolute scans
		Technical problems
Throughout season	51	Unknown reason
02/20/08 - 02/22/08	53	Overheating of laboratory and instrument, affecting responsivity
04/22/08 - 04/25/08	32	Shutter did not open completely
04/26/08	29	Missing for unknown reasons
05/15/08 - 05/21/08	516	Overheating of laboratory and instrument, causing automatic shut-down of instrument to prevent further damage
05/26/08	15	Overheating of laboratory and instrument, affecting responsivity
10/09/08	9	Shutter did not open completely

10/22/08	13	Shutter did not open completely
11/15/08	7	Shutter did not open completely
03/07/09 - 03/08/09	3	Shutter did not open completely
03/12/09 - 03/03/09	18	Shutter did not open completely
03/24/09 - 03/26/09	9	Shutter did not open completely
04/07/09 - 07/14/09	45	Shutter did not open completely
04/15/09 - 04/17/09	39	Instrument service including repair of shutter
04/20/09	32	Missing for unknown reasons

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 2008 and 2009 were processed separately. Data products were calculated from calibrated measurements (Section 4.3.2). Figure 5.6.9. shows a comparison of GUV-511 and SUV-100 erythemal irradiance based on final Volume 18 data. For solar zenith angles smaller than 75°, measurements of the GUV-511 instrument are on average 1.3% larger than SUV-100 measurements. The bias between the two instruments depends somewhat on season. Some of the seasonality is caused by the simplifications of the GUV 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°.

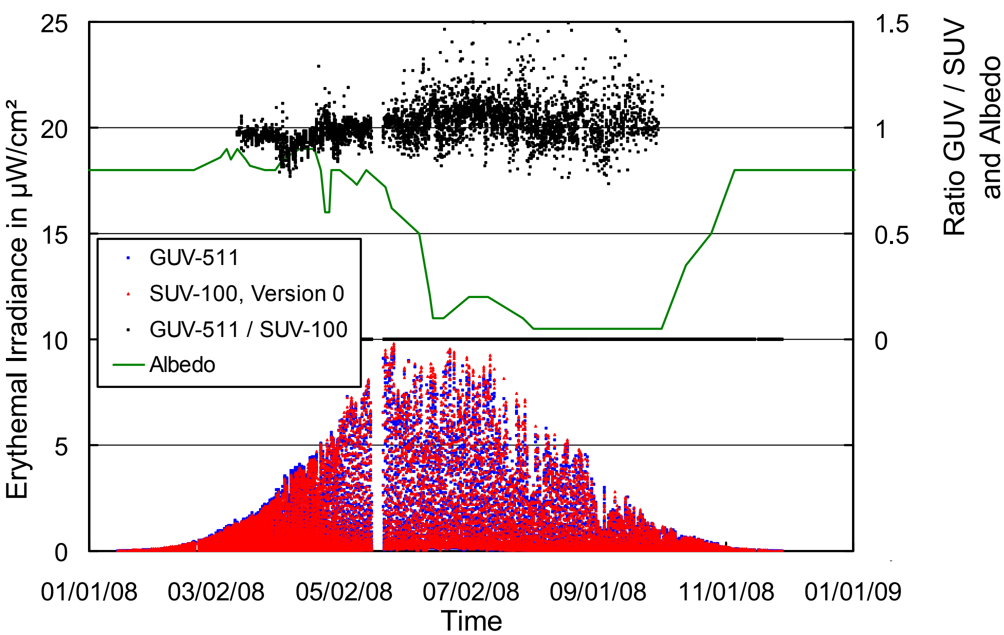

Figure 5.6.9. *Comparison of erythemal irradiance measured by the SUV-100 spectroradiometer and the GUV-511 radiometer. Data are based on "Version 0" (cosine-error uncorrected) data. The green curve indicates albedo and was taken from Version 2 data, available at www.biospherical.com/nsf/Version2.*

Figure 5.6.10 shows a comparison of total ozone measurements from the GUV-511, the Ozone Monitoring Instrument (OMI) on NASA's AURA satellite (Version 8.5, Collection 3), the SUV-100 (Version 2 data using climatological profiles with temperature correction), 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 on average 2.4% lower than OMI data. 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 3.1% and Dobson measurements by 2.7%, on average. These discrepancies can partly be explained by the different ways ozone and temperatures profiles are treated by the different retrieval methods. For more information on total ozone calculation from SUV-data at Barrow see *Bernhard et al*., 2003. The effect of the vertical distribution of ozone has been further discussed by *Bernhard et al*., 2005.

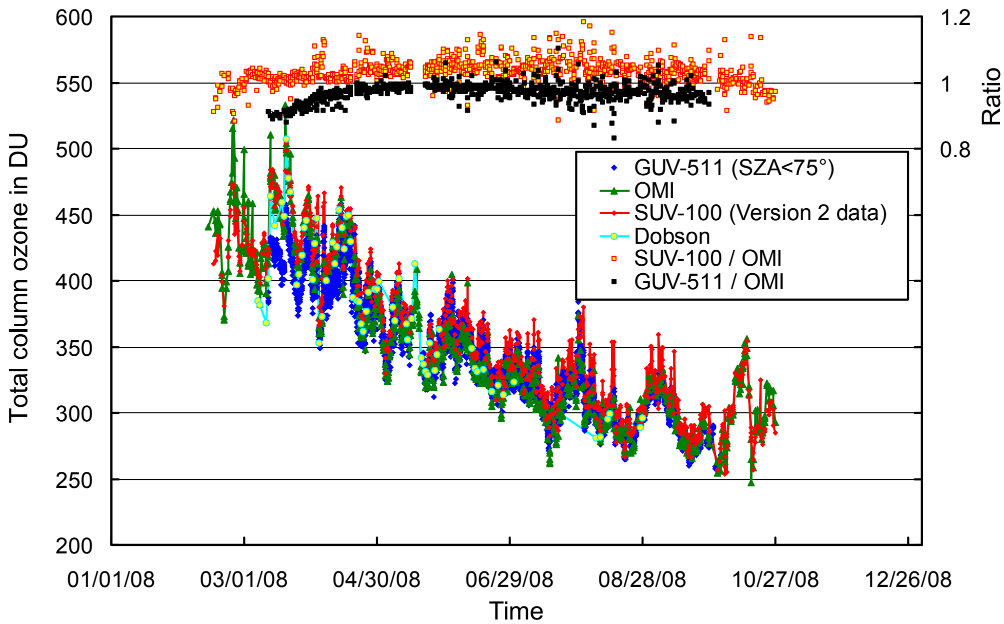

Figure 5.6.10. *Comparison of total column ozone measurements from GUV-511, OMI, SUV-100, and Dobson. GUV-511 measurements are plotted in 30 minute intervals. For calculating the ratios of SUV-100/OMI and GUV-511/OMI, only measurements concurrent with the OMI overpass were evaluated.*