5.6. Barrow, Alaska (07/13/09 – 11/28/10)

This section describes quality control of solar data recorded at Barrow between 07/13/09 and 11/28/10. Data of the period 07/13/09 – 12/31/09 were assigned to Volume 19; data of 2010 were assigned to Volume 20.

The system ran all but unattended 4/17/09 and 3/3/10 due to a breakdown in support contract arrangements. No calibration scans could be performed during this period and the instrument's collector was only cleaned occasionally. The system was regularly checked from BSI using remote-access software. The unfortunate support situation led to reduced data yields and increased uncertainty, however, no catastrophic system failure occurred and a good fraction of the data could be salvaged and published.

The site was visited between 3/3/10 and 3/11/10 by BSI personnel who performed instrument repairs, characterizations, and calibrations. Also during this time, two research associates in the employ of Arctic Administrators were trained in instrument operation and calibration. For the rest of the year, the two persons performed regular checks and calibrated the system bi-weekly.

Data collected during the reporting period are affected by the following problems:

- Uncertainty of radiometric calibration
  As no absolute scans were performed between 4/17/09 and 3/4/10, the radiometric calibration for this period is uncertain. Drifts of the SUV-100 spectroradiometer were assessed by comparing SUV-100 measurements with radiative transfer model calculations. For years prior to 2009, measurements of the SUV-100 during clear sky periods typically agreed to within a few percent with the model when the input parameters of the model were well defined. This is usually the case during summer when the surface albedo is very low. Up to the end of May 2009, SUV-100 measurements for clear-sky conditions agreed well with the model. Between July and September 2009, the SUV-100 measurements were lower than the model by 15% at 320 nm, 10% at 370 nm, 7% at 400 nm, 6% at 450 nm, 4% at 500 nm and 590 nm. All measurements performed between 7/13/09 and 11/28/10 were scaled up by this amount as part of Version 2 processing. There were no clear sky days in October and November 2009 to test whether the scaling was also appropriate for these two months. Published Version 2 data for these months should therefore not be used for trend analysis. Version 0 data of the period 7/13/09 - 11/28/09 were not published because of these uncertainties, but Version 2 data are available.

  We also considered comparisons between SUV-100 data and measurements of the co-located GUV-511 instrument to determine changes in the SUV-100's responsivity that may have occurred in 2009. This method usually works well as the GUV-511 typically drift by less than 2% over one year. Unfortunately, the comparison did not lead to conclusive results for the data collected in the fall of 2009 as both instruments were not cleaned over extended (> 1month) periods of time. We concluded that the comparison with the model is the best method for correcting the SUV-100 measurements.

- Reduced duty cycle
  In April 2008, the instrument's shutter started to become "sticky" and did not fully open during solar scans. The shutter was repaired in March 2009. To a prevent similar problem (overheating of the shutter solenoid) in the future, the system's duty cycle was reduced from four to two scans per hour up to 3/23/2010. From 3/27/10 onward, the regular duty cycle of four scans per hour was re-established.

- Increased temperature variability
  The instrument's thermoelectric cooler failed sometime in 2009, leading to excessive instrument temperatures during July and August 2009, and March-June 2010. Also the temperature of the

system's monochromator exceeded its set value of 33 °C during several days during this period, leading to reduced system responsivity. Data of periods most affected by the problem were removed from the published data set.

Periods with increased uncertainty are listed in Table 5.6.1. A total of 3873 SUV scans are part of the Barrow Volume 19 dataset (Version 2 data only!) and 16010 scans are part of Volume 20.

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. 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 three lamps were compared to the travel standard 200W017 in March 2010. The calibration of lamp 200W017 is traceable to the NIST1990 scale in the same way as lamp 200W042. Figures 5.6.1 shows a comparison of the three site standards with lamp 200W017, performed on 3/9/10. The calibrations of the lamps agree to within ±1.5%.

The three site standards were also compared with each other on 7/18/10 and 11/7/10. Measurements agreed to within ±1.5%. Figure 5.6.2 shows the result of the comparison performed on 7/18/10.

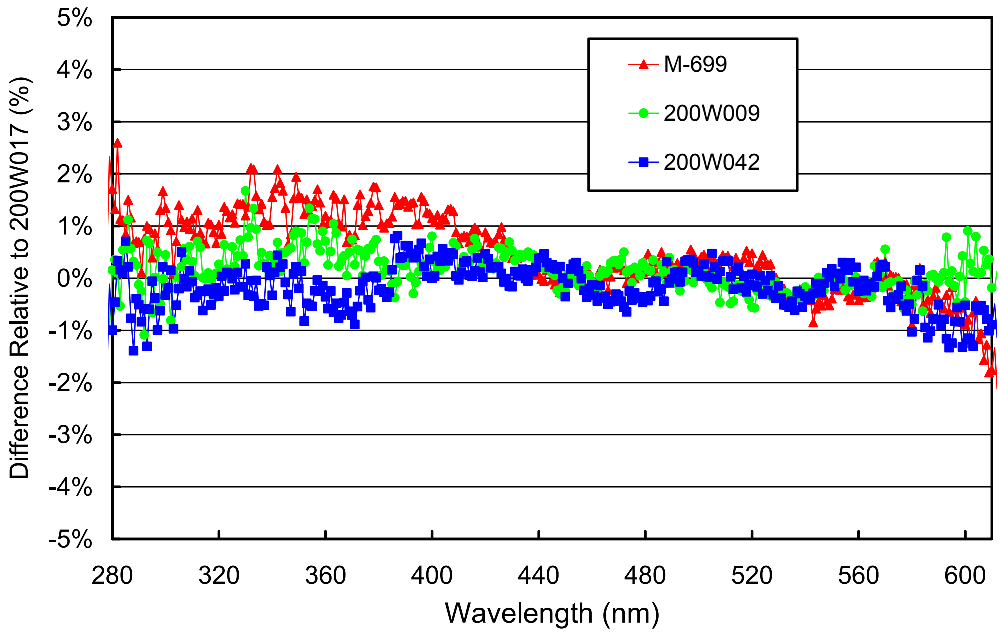

Figure 5.6.1. *Comparison of on-site lamps 200W009, M-699 and 200W042 with traveling standard 200W017 on 3/9/10.*

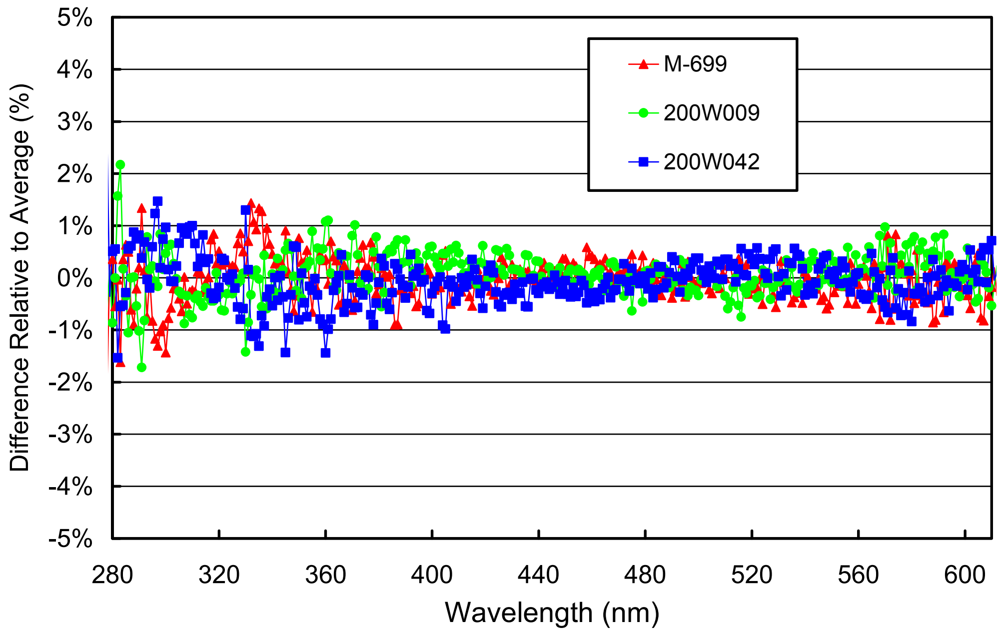

Figure 5.6.2. *Comparison of on-site lamps 200W009, M-699 and 200W042 on 7/18/10.*

5.6.2. Instrument Stability and Calibration

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 could not be applied to data collected between 07/13/09 and 3/7/10 as no absolute scans were performed during this period. For the period of 07/13/09 - 11/28/09, the responsivity file calculated for the period 06/25/09 - 07/12/09 (last calibration period of Volume 18) was applied, but scaled upward by 15% at 320 nm, 10% at 370 nm, 7% at 400 nm, 6% at 450 nm, 4% at 500 nm and 590 nm. The scale factors were determined using radiative transfer calculation. The calibrations for solar measurements of the period 01/01/10 - 03/04/10 was based on absolute scans performed at the start of the March 2010 site visit before the instrument was removed for service. Solar measurements performed after 03/07/10 were calibrated in the normal way using absolute scans performed every two weeks. A summary of calibrations applied to solar data of the reporting period is provided in Table 5.6.1. The ratio of calibration functions for the periods P2 - P6 to the function applied in period P1 (01/01/10 - 03/04/10) is shown in Figure 5.6.3.

Figure 5.6.4 presents ratios of standard deviation and average spectra, calculated from individual absolute scans performed in each calibration period. These ratios are useful for estimating the variability of calibrations assigned to each period. The variability is less than 2% for all periods.

The internal reference standard of the instrument was reasonable stable during the reporting period, allowing to assess the stability of the instrument’s monochromator and photomultiplier detector (PMT). Note that measurements of the lamp are not suitable to track changes of the instrument’s through-the-collector response. Figure 5.6.5 shows changes in TSI readings and PMT currents at 300 and 400 nm that were derived from the daily response scans. TSI measurements decreased steadily by about 4% over the reporting period. PMT currents track measurements of the TSI very well, indicating good stability of monochromator and PMT. The responsivity changed by about 5% in March 2010 when the system was serviced. The increased variability in all variables observed between mid-May and mid-June 2010 was caused by excessive instrument temperatures due to the mal-functioning thermoelectric cooler.

All SUV-100 data were also compared to measurements of the collocated GUV-511 radiometer. There is a clear correlation of the GUV/SUV ratio with the temperature of the SUV’s monochromator (Figure 5.6.6).

SUV measurements tend to be low when the monochromator temperature is high. Data measured at times when the monochromator temperature was larger that 38 °C were not published. The ratio of final GUV and SUV data at 340 nm as a function of time is shown in Figure 5.6.7. Data of both instruments are typically consistent at the ±5% level but some dependence with monochromator temperature is still apparent in this plot.

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.

Table 5.6.1: Calibration periods of Barrow Volume 19 and 20 data.

Period	Period range	Scans*	Remarks	Possible Bias+
P0	07/31/09-11/28/09	0	Calibration of Period P5B of Volume 18 data (which was applied to period 06/25/09-07/12/09), scaled upward by 15% at 320 nm, 10% at 370 nm, 7% at 400 nm, 6% at 450 nm, 4% at 500 nm and 590 nm.	±5% for July - September 2009, possibly -10% for October and November 2009) when SZA is larger than 75°
P1	01/01/10-03/04/10	4	Scans performed at the beginning of site visit on 3/4/10	up to +5%
P2	03/05/10-03/24/10	6		
P3	03/25/10-06/07/10	4		
P4	06/08/10-09/05/10	8		
P5	09/06/10-09/17/10	1	Average of the one calibration scan performed in this period and the average of calibrations applied in Periods P4 and P6.	
P6	09/18/10-12/31/10	6		

* Number of absolute scans performed in given period.
+ Indicated by GUV/SUV comparison. Positive values suggest that SUV-100 data are too high.

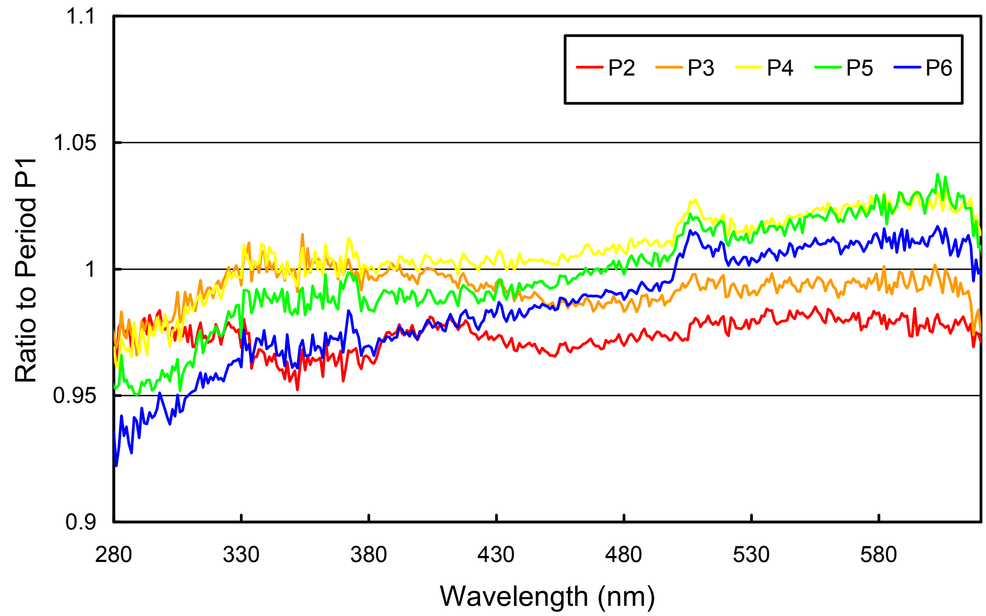

Figure 5.6.3. *Ratios of spectral irradiance functions assigned to the internal reference lamp during the Periods P2 – P6, relative to Period P1 (1/1/10 - 3/4/10).*

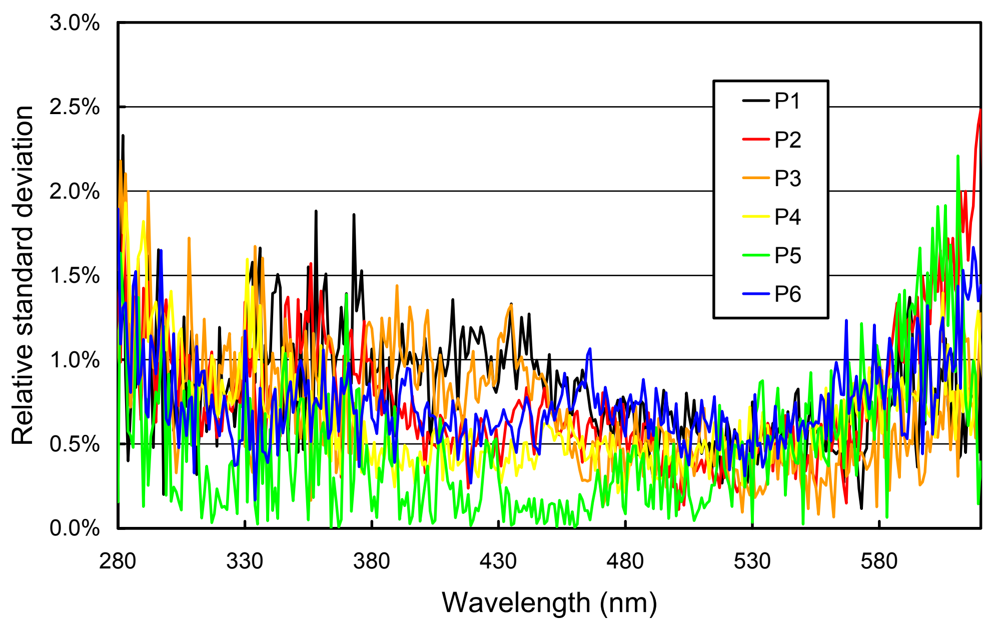

Figure 5.6.4. *Ratio of standard deviation and average spectra calculated from absolute calibration scans.*

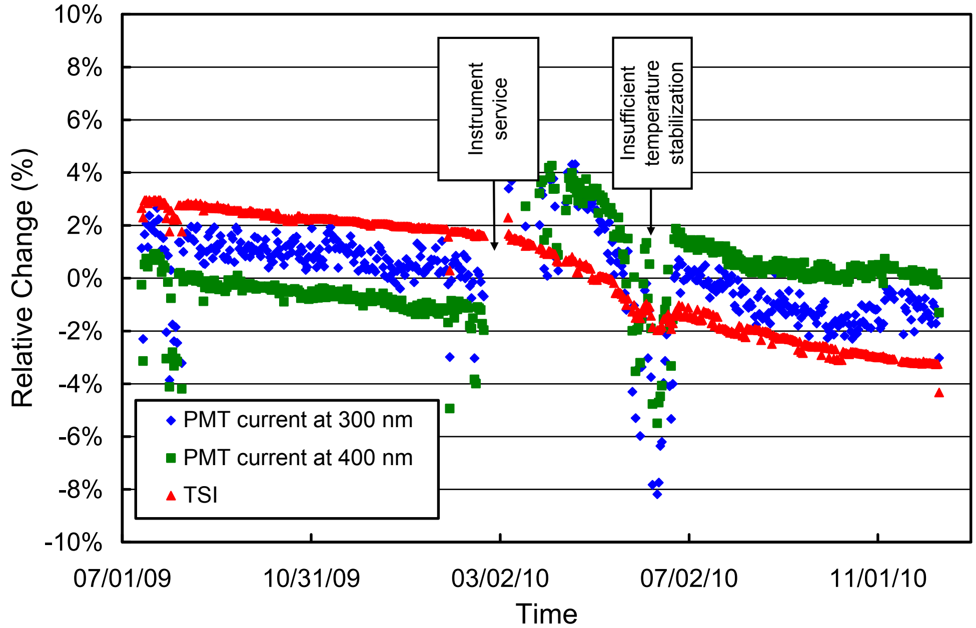

Figure 5.6.5. *Time-series of PMT current at 300 and 400 nm, and TSI signal extracted from measurements of the internal irradiance standard at Barrow between 7/13/09 – 12/10/10. All data sets are normalized to their average.*

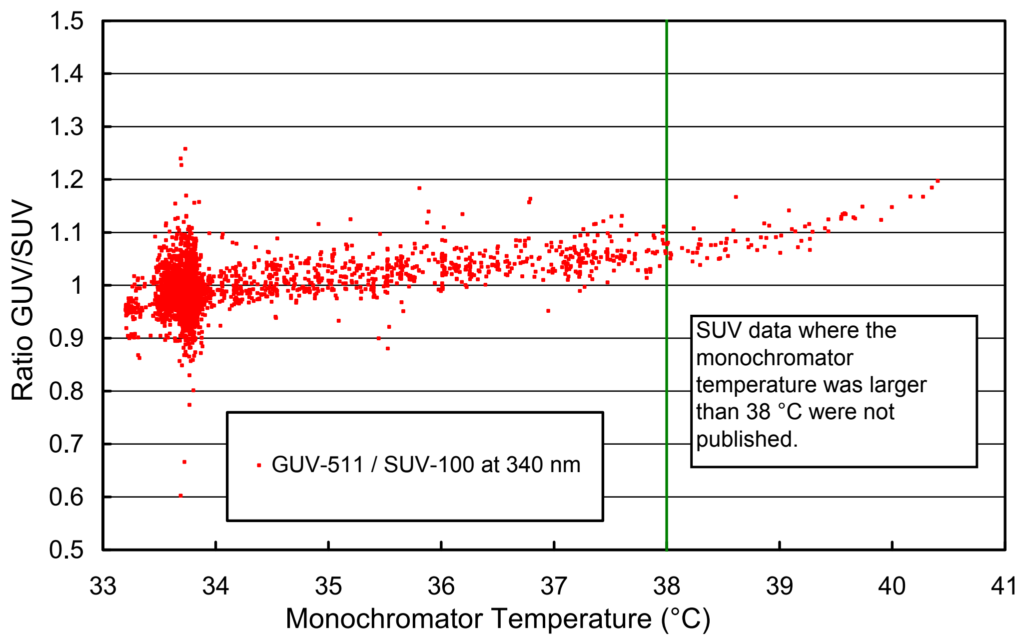

Figure 5.6.6. *Ratio of GUV-511 measurements of the 340-nm channel to SUV-100 measurements as a function of monochromator temperature of the SUV-100.*

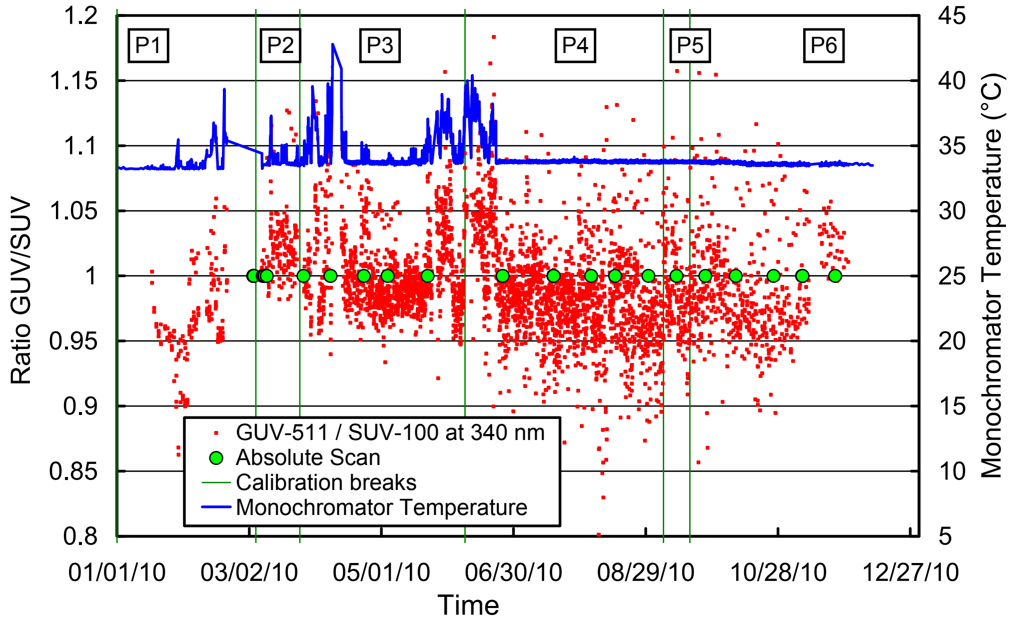

Figure 5.6.7. *Ratio of GUV-511 measurements of the 340-nm channel to SUV-100 measurements. The latter were weighted with the spectral response function of the 340-nm GUV-511 channel. Measurement at times when the monochromator temperature (blue data set, right axis) of the SUV-100 exceeded 38 °C were not published and are not included in this figure. Times of absolute scans and calibration breaks are also indicated.*

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 5.6.8 shows the differences in the wavelength offset of the 296.73 nm mercury line between two consecutive wavelength scans. In total, 542 pairs, measured between 7/13/09 and 12/10/10, were evaluated. In 87% (95%) 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. Most larger changes in wavelength offset were related to system maintenance during the site visit.

Two functions for correcting the non-linearity of the monochromator's wavelength drive were implemented and are shown in Figure 5.6.9. 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 5.6.10. Residual shifts in the UV are typically smaller than ±0.05 nm and have been further reduced in the Version 2 data set.

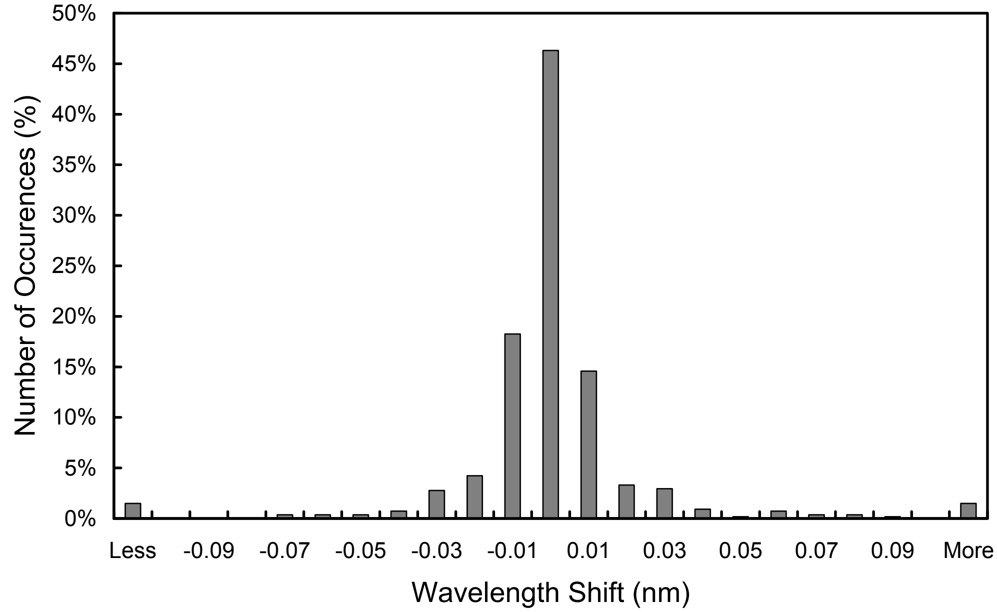

Figure 5.6.8. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans. The x-labels give the center wavelength shift for each column. Thus the 0-nm histogram column covers the range -0.005 to +0.005 nm. "Less" means shifts smaller than –0.105 nm; "more" means shifts larger than 0.105 nm.*

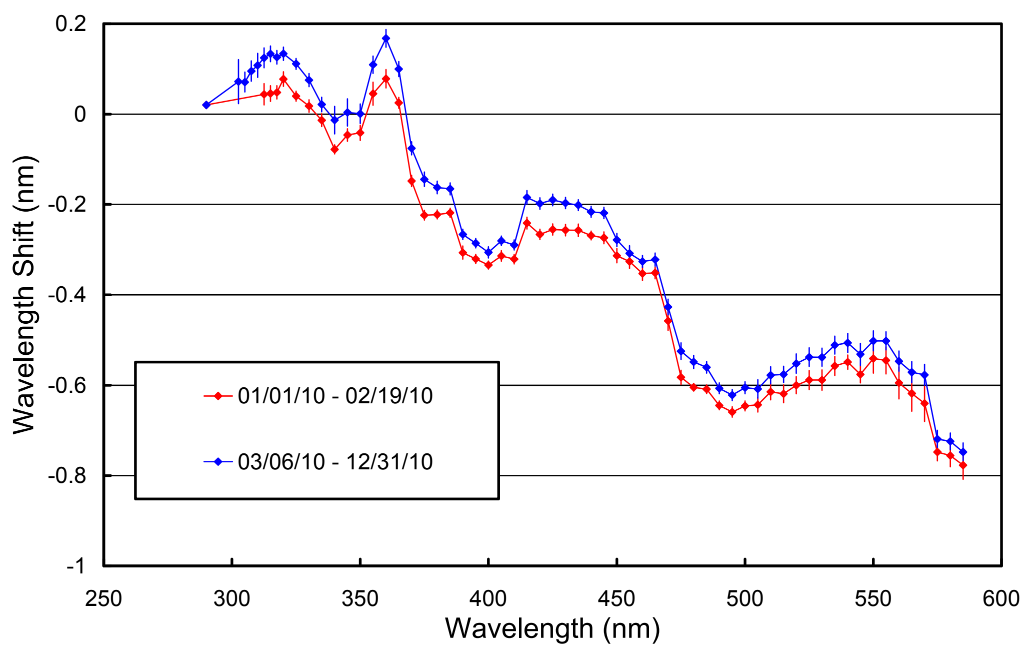

Figure 5.6.9. *Monochromator non-linearity correction functions for Barrow Volume 20.*

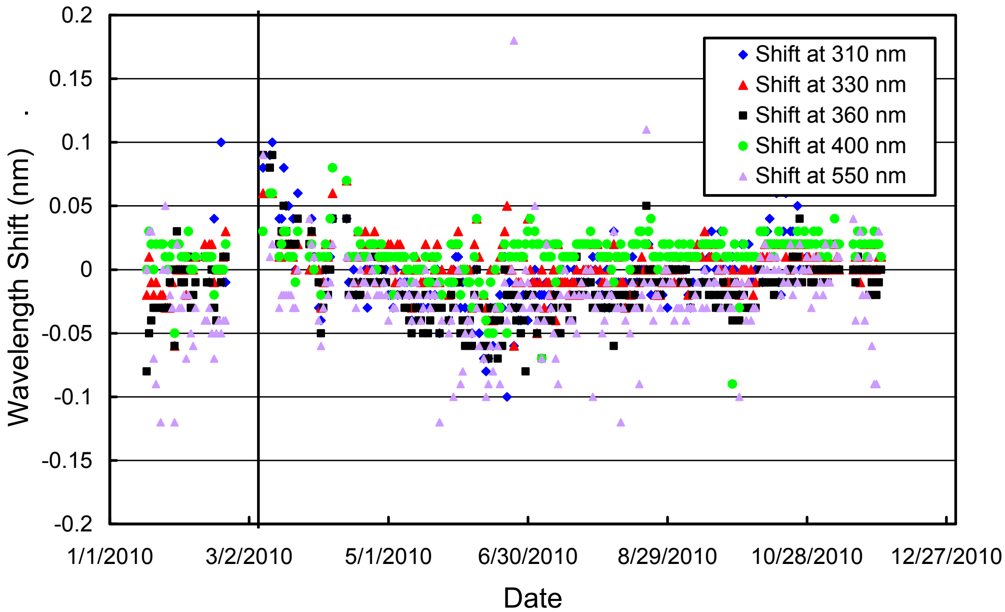

Figure 5.6.10. *Wavelength accuracy check of final data at four wavelengths in the UV and one in the visible by means of Fraunhofer-line correlation. The noontime measurement has been evaluated for each day of the reporting period when the Sun was above the horizon. The vertical line indicates the time when the monochromator non-linearity correction function was changed.*

5.6.4. Missing Data

Version 0 data of the period 7/13/09 - 11/28/09 were not published because of large uncertainties related to insufficient on-site support during this period. Version 2 data were published using radiative transfer model calculations to quantify and correct systematic error in the Version 0 data set. The number of Version 2 spectra published for this period is 3873. There are no significant gaps in this dataset.

A total of 16010 scans are part of the Barrow Volume 20 dataset (1/16/10 - 11/28/10). There are no data for the following periods:

- 2/8/10, 2/9/10 — Cause unknown
- 2/22/10 - 3/6/10: — System overheated, site visit
- 3/24/10 - 3/26/10: — Monochromator has lost wavelength position
- 3/30/10: — System overheated due to defective thermoelectric cooler
- 4/9/10 - 4/11/10: — System overheated due to defective thermoelectric cooler
- 5/23/10 - 5/25/10: — System overheated due to defective thermoelectric cooler
- 6/9/10: — System overheated due to defective thermoelectric cooler (The cooler was repaired on 6/22/10)
- 10/6/10: — Power outage
- 11/12/10 - 11/14/10: — Computer problems.

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 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 20 data. For solar zenith angles smaller than 75°, measurements of the GUV-511 instrument are on average 4% 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, in particular when the SZA exceeds 75°.

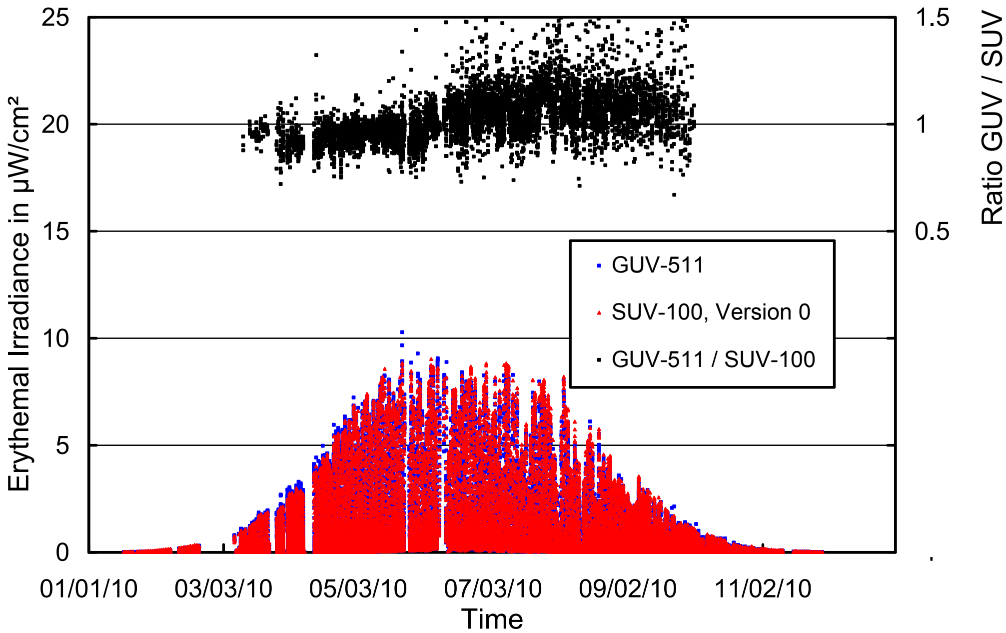

Figure 5.6.11 *Comparison of erythemal irradiance measured by the SUV-100 spectroradiometer and the GUV-511 radiometer. Data are based on "Version 0" (cosine-error uncorrected) data.*

Figure 5.6.12 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), and the SUV-100 (Version 2 data using climatological profiles with temperature correction). GUV-511 ozone values were calculated as described in Section 4.3.3. GUV-511 data measured between April and September are on average 1.2% larger than OMI data. In February in March, when the Sun is low and the ozone column large, GUV-511 measurements tend to be low by about 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 approximately 3%, independent of time of the year. The 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.

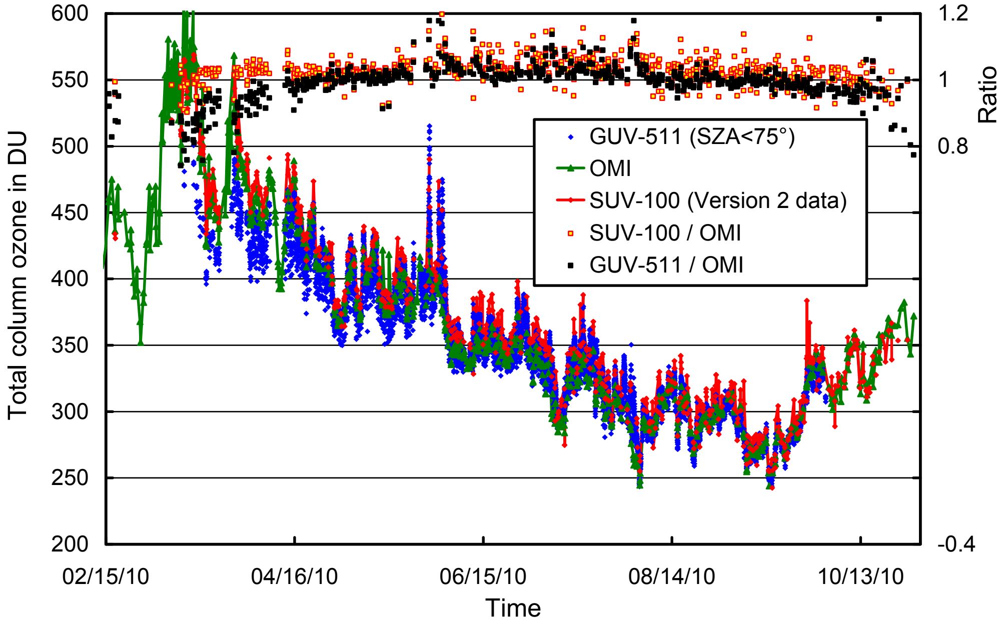

Figure 5.6.12. *Comparison of total column ozone measurements from GUV-511, OMI, and SUV-100. GUV-511 measurements are plotted in 30 minute intervals. For calculating the ratios of SUV-100/OMI and GUV-511/OMI, only measurements concurrent with the OMI overpass were evaluated.*

References

Bernhard, G., C.R. Booth, and R.D. McPeters. (2003). Calculation of total column ozone from global UV spectra at high latitudes. J. Geophys Research, 108(D17), 4532, doi:10.1029/2003JD003450.

Bernhard, G., R.D. Evans, G.J. Labow, and S.J. Oltmans. (2005). Bias in Dobson Total Ozone Measurements at High Latitudes due to Approximations in Calculations of Ozone Absorption Coefficients and Airmass. J. Geophys. Res., 110, D10305, doi:10.1029/2004JD005559, 2005.