5.7. Summit, Greenland (01/22/12 – 11/22/12)

This section describes quality control of “Volume 22” solar data recorded by the SUV-150B spectro-radiometer at Summit Camp, Greenland, between 01/22/12 and 11/22/12.

Periodic changes in responsivity of the SUV-150B spectro-radiometer observed during the last years continued in 2012. These changes are caused by variations in collector efficiency and PMT sensitivity. The chances are now well understood and were corrected during data processing. Residual variations in published data were assessed by comparing SUV-150B data with measurements of the co-located GUV-511 multi-filter radiometer and results of radiative transfer calculations, and are smaller than ±2%.

The instrument is located in the “Green House” of Summit Station. The building is resting on compacted snow, tends to tilt over time, and gets buried in snow. Every few years, the building is being “dug out” and re-erected on a fresh patch of snow. Such an event occurred in the second half of May 2012. Before that time, the Green House was tilted by more than 2° and the top of the building was only slightly above the surrounding snow surface. Snow drifts affected the UV measurements during several days in April and May. Because the collector of the SUV-150B is installed into the roof of the Green House, it cannot be leveled accurately if the tilt of the building exceeds a certain amount. This was the case between January and May 2012 when the collector was out of alignment by up to 1.2° in northern direction and up to 0.7° in western direction. There are no solar measurements during the time when the Green House was relocated (5/22/12 - 5/30/12). The system was operational again on 5/31/12, however, its collector was not leveled until 6/15/12 and was out of alignment by up to 1.1° in northern direction and up to 0.4° in western direction. After 6/15/12 and until the end of the reporting period, the collector was level to within ±0.1° in both directions.

During times when the collector was out of alignment, an azimuthal asymmetry is apparent in solar measurements. This systematic error was reduced (but not completely eliminated) as part of the Version 2 cosine error correction. Version 0 data described in this report remain affected by this error. Version 2 data, which are available at uv.biospherical.com\Version2, were processed in three batches, applying different cosine error correction for the three “tilt” periods (i.e., the period before the relocation of the Green House, the period before realigning the collector, and the final period when the collector was level).

The fuse of the power supply powering the system’s internal reference lamp failed on 2/15/12. It was replaced on 2/22/12. There are no “response” scans between 2/15/12 and 2/22/12. The response scan of 2/14/12 was used for data processing.

Measurements of the TSI sensor internal to the SUV-150B were not always correctly recorded. Defective data were removed from the published databases.

During some scans, the collectors of the SUV-150B and GUV-511 were shaded by nearby obstacles. Shading events occurred mostly between 8:30 and 9:00 between mid-April and mid-August and during various times of the day in April and May. Affected scans were not removed from the Version 0 dataset, however, they were flagged in the Version 2 dataset.

The Eppley PSP pyranometer (S/N 32760F3) installed next to the SUV-150B was calibrated by Eppley Laboratories on 7/30/2009. The calibration factor is 7.94 V/(W m^{-2}).

A total of 17211 scans are part of the Summit Volume 22 dataset.

5.7.1. Irradiance Calibration

The on-site irradiance standards used during the reporting period were the lamps 200W027, 200W030, and 200W038. Lamp 200W017 served as a traveling standard.

Calibration history of traveling standards 200W017
Lamp 200W017 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. Values of spectral irradiance provided in certificates issued by the CUCF were converted to the NIST1990 scale before the calibration was transferred to lamp 200W017.

The irradiance scale of lamp 200W017 was checked in November 2012 against the scale of the four CUCF lamps mentioned above; the scale of NIST standard F-474, which is traceable to the NIST1990 scale; and the scale of standard F-616, which was calibrated by NIST in August 2008 against the NIST2000 scale. Lamp F-616 is the primary standard for the NASA "OSPREy" project (http://www.biospherical.com/index.php?option=com_content&view=article&id=94&Itemid=92) because it was calibrated by NIST recently, is traceable to the latest scale issued by NIST, and burns very stable. The voltage drop across the lamp's terminals measured by NIST is identical to that measured at BSI to within 10 mV (0.01%), giving additional confidence that the lamp has not changed since it has left the NIST facility.

For this lamp comparison, the four CUCF lamps, lamp F-474, and lamp 200W017 were first calibrated against lamp F-616 using a "transfer GUV" (XGUV) radiometer with channels between 290 and 875. The XGUV was chosen because it can be used both with lamps that have a vertical beam (e.g., the four CUCF lamps and 200W017) and a horizontal beam (F-474, F-616). The previous spectral irradiances assigned to the lamps were ratioed against the new set of values established with lamp F-616. The resulting ratios are shown in Figure 5.7.1. Two data sets were included for the CUCF lamps: the data set shown as a solid red line is based on the original spectral irradiances provided by CUCF (which is traceable to the NIST2000 scale) while the dotted red line is based on the modified dataset that was scaled to the NIST1990 scale. The dotted read line and the orange line (representing lamp F-474) agree to within ±0.5%, indicating that the modified spectral irradiance scale of the four CUCF lamps does indeed agree with the NIST1990 scale.

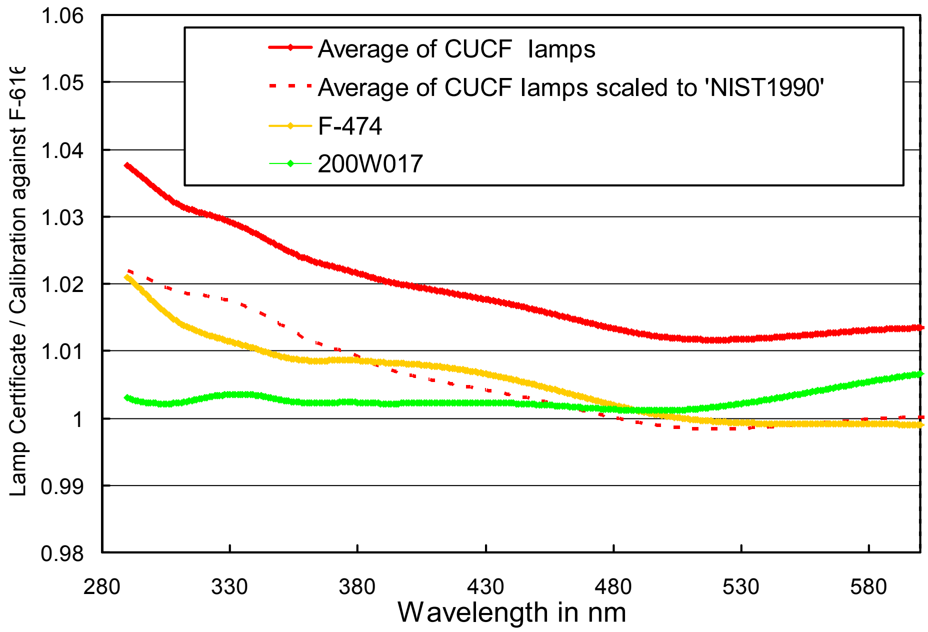

Figure 5.7.1. *Irradiance scale of CUCF lamps, NIST lamp F-474, and traveling standard 200W017 relative to irradiance scale of NIST standard F-616. The ratio indicated by the dotted red line was constructed by scaling the scale of the CUCF lamps to the NIST1990 scale and comparing the result with the scale represented by NIST standard F-616.*

Figure 5.7.1 also indicates that the original scale of the CUCF lamps differs systematically from the scale represented by lamps F-616. The difference is 4% at 290 nm, 3% at 330 nm, 2% at 400 nm, and between 1-2% in the visible. This result is surprising because all lamps in question are traceable to the NIST2000 scale. The reason for the discrepancy is unknown as of this writing and under further investigation.

The spectral irradiance scale of the travelling standard 200W017 agrees to within 0.7% with that of lamp F-616. At wavelengths above 320 nm, there is also good (i.e., better than ±1%) agreement with the scales of F-474 and the NIST1990 scale of the four CUCF lamps. The difference increases towards shorter wavelengths and is 1.8% at 290 nm. This discrepancy is still within the combined uncertainty of the NIST1990 and NIST2000 scales.

The analysis confirmed that the spectral irradiance scale of lamp 200W017, established in June 2007, still agrees with the NIST1990 scale to within NIST's uncertainty specification. Lamp 200W017 is therefore still a valid reference for calibrating or checking on-site standards.

Calibration history of on-site standards 200W027, 200W030, and 200W038

Lamp 200W027 was originally calibrated on 3/28/01 by Optronic Laboratories. The lamps was recalibrated against lamp 200W017 using "closing" scans performed at Summit on 7/11/07. These calibrations were used for processing solar data of the Volume 16 period. Lamp 200W027 was temporarily moved to San Diego and was recalibrated in March 2008 against lamps 200W028 and 200W022. The lamp was recalibrated again in November 2011 against standards 200W017 and 200W038. This calibration was used for processing of solar data of the Volume 21 (2011) and Volume 22 (2012) periods.

Lamp 200W030 was originally calibrated on 3/28/01 by Optronic Laboratories. The lamps was recalibrated against lamp 200W017 using "closing" scans performed at Summit on 7/11/07. The lamp was recalibrated in June 2009 against 200W017 using "closing" scans of the Volume 18 period. This calibration was used to process solar data of the period 01/20/11 – 07/01/11. The lamp was recalibrated again in November 2011 against the traveling standards 200W017 and 200W038. This calibration was used for processing data of the reporting period.

Lamp 200W038 was calibrated against lamps 200W028 and 200W022 in April 2008. At this time, the calibration of lamp 200W038 was consistent to that of 200W017.

Figure 5.7.2 compares the calibration of the on-site standards 200W027, 200W030, and 200W038 with that of the traveling standard 200W017. The comparison is based on absolute scans performed at Summit in November 2011. The irradiance scales of the three on-site standards agree with each other to within ±0.5%. The bias between the scales of the three lamps and lamp 200W017 is smaller than 1%, except for lamp 200W038, which differs from lamp 200W017 by 2% at 360 nm. The three on-site standards were also compared with each other on 2/8/12, 6/16/12, 7/2/12, and 11/8/12. The calibrations agreed to within ±1% on all occasions, giving confidence in the calibration applied to solar data of the reporting period.

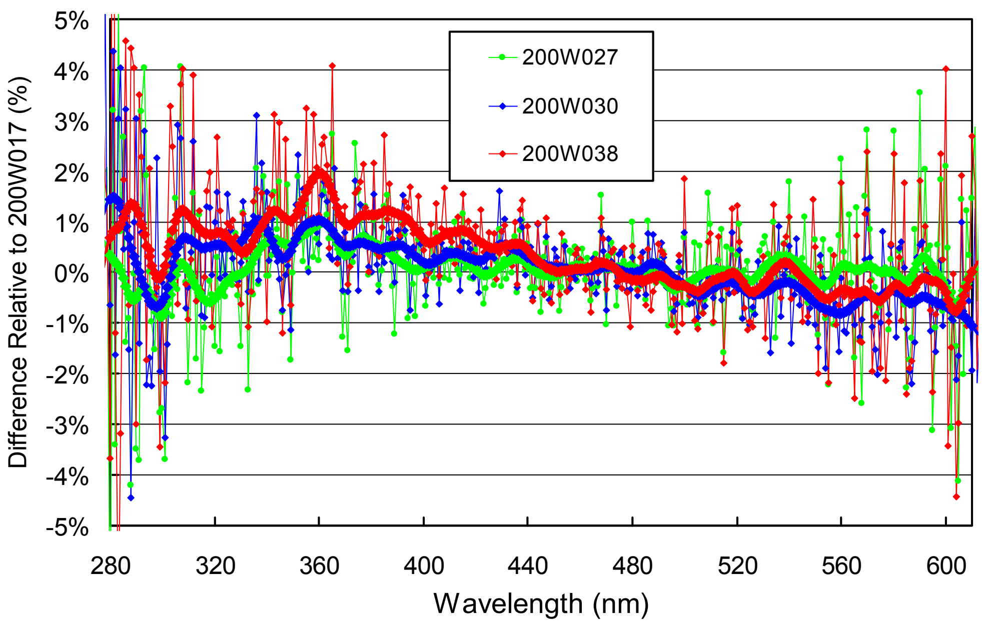

Figure 5.7.2. *Comparison of lamps 200W027, 200W030, and 200W038 with 200W017 on 3-4 November 2011. Heavy solid lines indicate smoothed data.*

5.7.2. Instrument Stability

The temporal stability of the spectroradiometer is monitored with bi-weekly calibrations utilizing the on-site standards; daily response scans of the internal irradiance reference lamp; and by comparison with the co-located GUV-511 radiometer and results from a radiative transfer model.

Internal to the instrument's fore optics is a filtered photo diode, called TSI, with a peak sensitivity in the UV. It is used to track changes in the light intensity of the internal reference lamp. By monitoring the TSI while measuring the current of the system's photomultiplier tube (PMT) detector, changes in the lamp output can be decoupled from drifts in monochromator throughput or PMT sensitivity. Figure 5.7.3 shows changes in TSI readings and PMT currents at 320 and 400 nm, derived from response scans performed between 2/14/06 and 12/19/12. TSI measurements changed by about 10% between 2/14/06 and 6/20/09. The lamp failed and the end of August 2009 and was replaced. Data recorded after this time were scaled downward by a constant factor to better compare with previous measurements. The relative change of the second lamp's intensity as recorded by the TSI between 9/2/09 and 12/19/12 is similar to that of the original lamp. The trend of PMT currents follows that of the TSI measurements but there is a sinusoidal variation with a periodicity of one year superimposed on the general trend. The highest PMT sensitivity is observed in mid-February of every year, while the lowest sensitivity is observed in August. We attribute this periodicity to a long-term memory of the PMT to the radiation levels it has “seen” during the months prior to the measurement. During the period of winter darkness, the PMT becomes more sensitive, and during the summer months its sensitivity decreases. As the variation is very predictable, it can be well corrected when solar data is processed.

To account for changes of the system’s sphere-throughput and PMT-sensitivity, the reporting period was broken into 15 sub-periods and a different irradiance spectrum was applied to the internal lamp in each period. Irradiance spectra were smoothed with an approximating spline to reduce the effect of measurement noise. A summary of the calibration periods is provided in Table 5.7.1. The ratios of irradiance spectra applied in Periods P2 - P6 relative to the spectrum applied in Period P1 are shown in Figure 5.7.4. After Period P6, the entrance optics of the instrument were removed from the main unit to facilitate releveling of the Green House. This service led a change in system sensitivity. The ratios of irradiance spectra applied in Periods P7 - P9 following the service relative to the spectrum applied in Period P7 are shown in Figure 5.7.5.

The quality of calibrated solar measurements of the SUV-150B was further assessed by comparison with the GUV-511 radiometer. Figure 5.7.6 shows the ratio of measurements of the GUV’s 340 nm channel to measurements of the SUV-150B. The latter have been weighted with the spectral response function of the GUV’s channel prior to forming the ratio. Measurements of the two instruments generally agree to within ±5%. The standard deviation of the ratio calculated from all data but the outliers discussed below is 2%. The variability is generally larger in spring than fall because measurements were affected by snow accumulation in the vicinity of the instruments’ collectors before the Green House was “dug out” and releveled.

A close-up of the period marked with “A” in Figure 5.7.6 is shown in Figure 5.7.7 and discussed in more detail below. The period marked with “B” extends from 5/30/12 to 6/15/12 and starts on the day the measurements resumed after releveling the Green House. During this period, the collectors of the SUV-150B and GUV-511 were not level, causing some diurnal variation in the ratio of measurements of the two instruments. Outliers occurring in the period marked with “C” were caused by shading of a nearby mast. The affected SUV scans were flagged in the Version 2 dataset.

The ratio of GUV and SUV exhibits a step change of 4% between 2/8/12 and 2/9/12 (period marked with “D” in Figure 5.7.7.) There is a series of three absolute scans at end of 2/8/12. The reason of the step change is unknown. SUV and GUV collectors were cleaned on 2/8/12 as well as 2/9/12. The calibration of the SUV was not adjusted because it could not be determined whether the step change was caused by the GUV or SUV. GUV data on 2/13/12 (Period E) and 3/7/12 (Period F) were too low because of snow accumulation on the instrument’s collector. Affected GUV data were removed from the published dataset. The ratio of Period G is 2 - 4% below the average, suggesting, that either GUV measurements are too low or SUV measurements are to high. Collectors of both systems were cleaned during this period. Like in the case of Period D, the calibration of the SUV was not adjusted because it could not be determined whether the comparatively small ratio was caused by the GUV or SUV.

Table 5.7.1. Calibration periods for Summit Volumes 22.

Period name	Period range	Number of absolute scans	Remarks
P1	01/01/12 – 02/02/12	2	
P2	02/03/12 – 02/13/12	3	
P2B	02/14/12 – 02/21/12	0	Average of P2 and P3
P3	02/22/12 – 02/28/12 and 03/03/12 – 04/02/12	3	
P3B	02/29/12 – 03/02/12	0	P3 scaled up by 1.05
P4	04/03/12 – 04/13/12	1	Average of P3 and P4
P4B	04/14/12 – 04/19/12	0	Average of P4 and P5
P5	04/20/12 – 04/28/12	1	
P5B	04/29/12 – 05/02/12	0	Average of P5 and P6
P6	05/03/12 – 05/28/12	1	
P7	05/29/12 – 06/23/12	3	
P7B	06/24/12 – 06/27/12	0	Average of P7 and P8
P8	06/28/12 – 07/20/12	4	
P8B	07/21/12 – 07/25/12	0	Average of P8 and P9
P9	07/26/12 – 12/31/12	11	

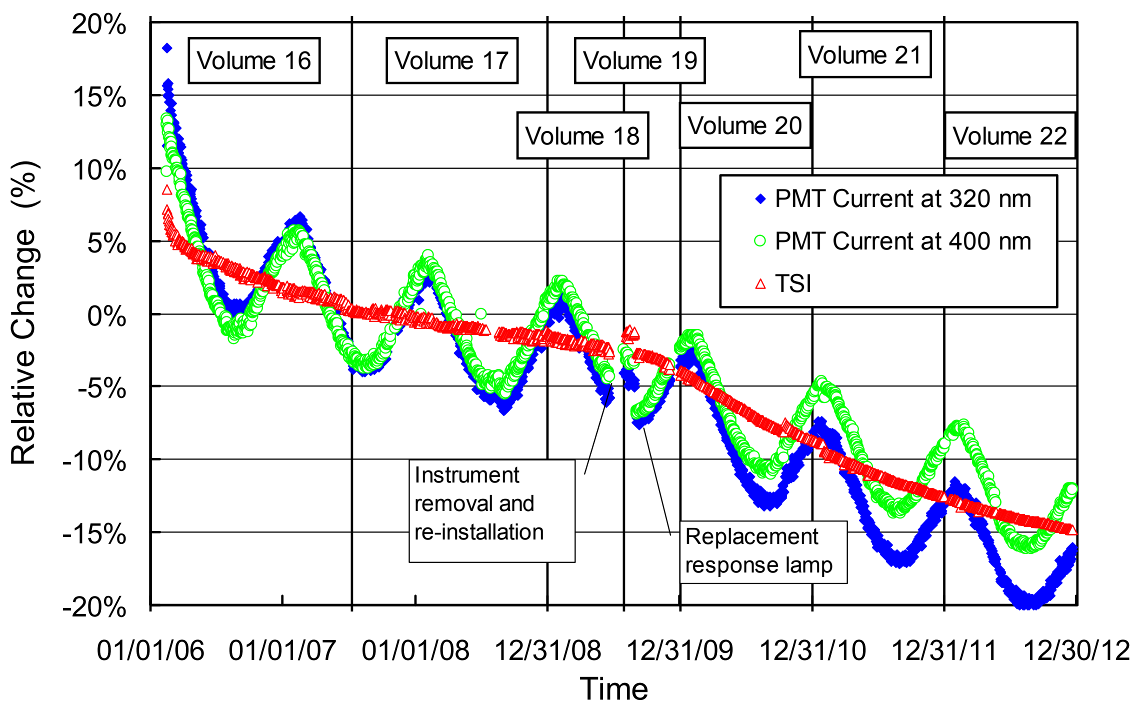

Figure 5.7.3. *Time-series of TSI signal and PMT currents at 320 and 400 nm during measurements of the internal reference lamp performed at Summit between 2/15/06 and 12/31/12. Data from 9/2/10 (date of response lamp replacement) were scaled to downward to fit into the existing pattern.*

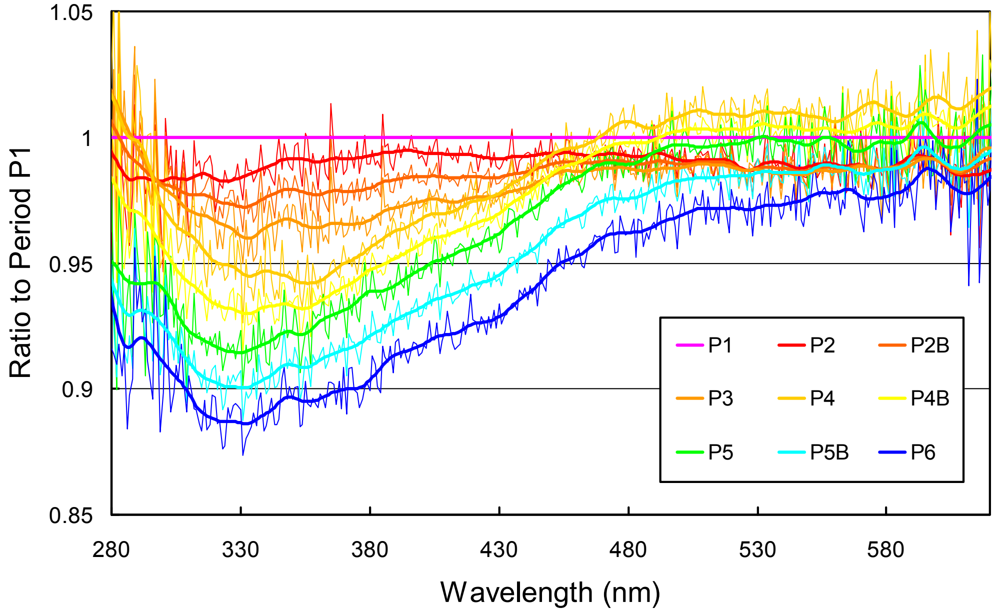

Figure 5.7.4. *Ratios of irradiance assigned to the internal reference lamp in Periods P2 – P6, referenced to the irradiance of Period P1. At the end of Period P6, the Green House where the instrument is installed was releveled. Thick lines indicate ratios of the smoothed irradiance spectra used for the calibration of solar measurements.*

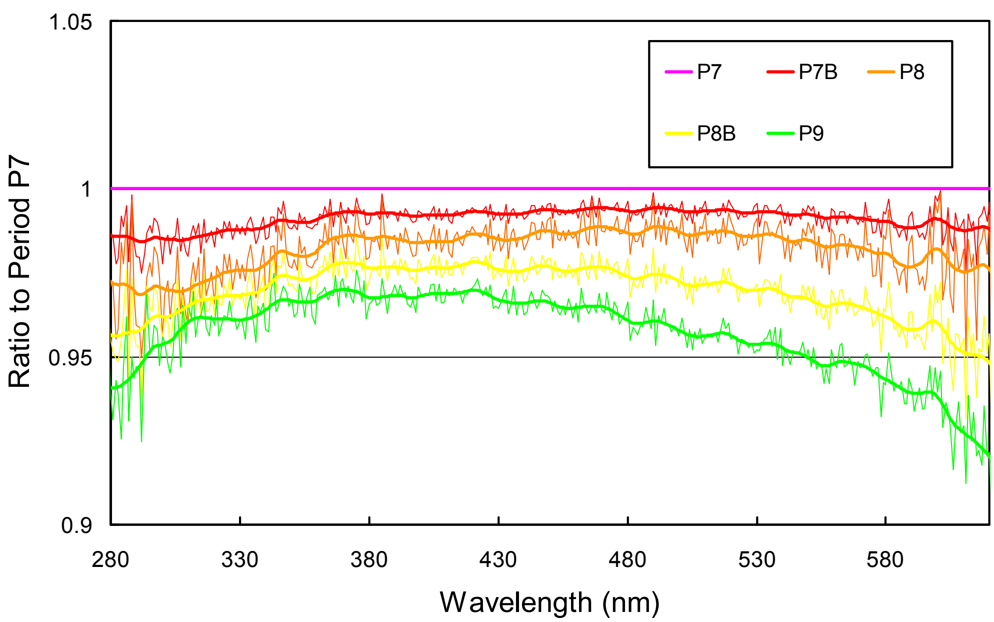

Figure 5.7.5. *Ratios of irradiance assigned to the internal reference lamp in Periods P7 – P9, referenced to the irradiance of Period P7, which is the first period following the leveling of the Green House. Thick lines indicate ratios of the smoothed irradiance spectra used for the calibration of solar measurements.*

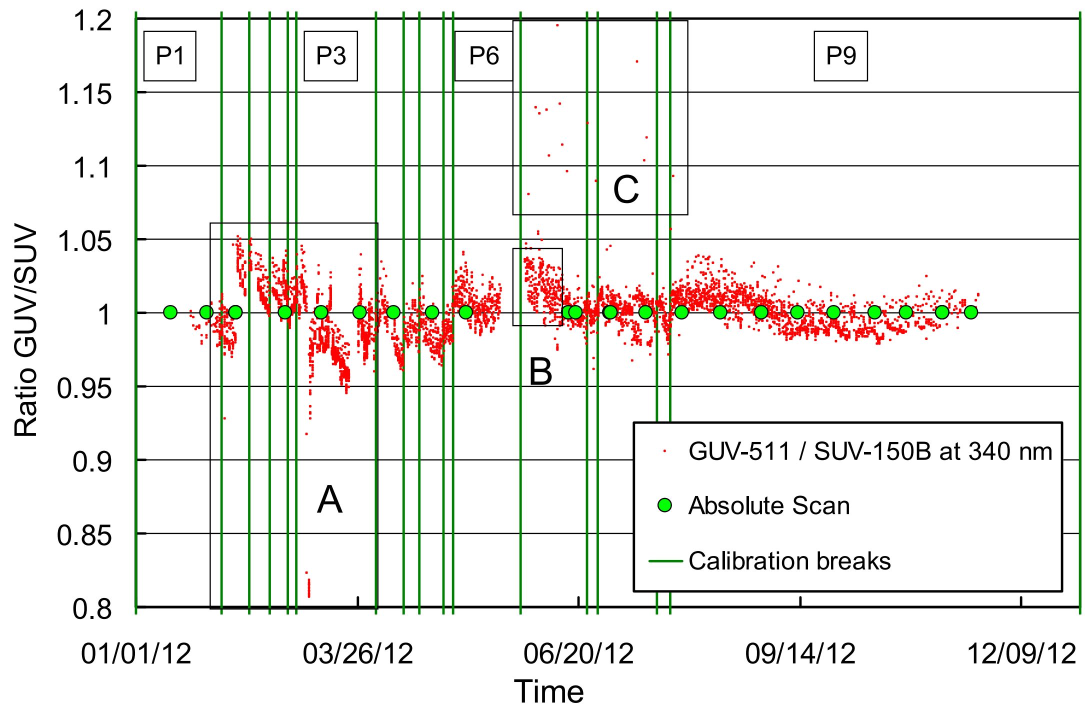

Figure 5.7.6. *Ratios of GUV-511 and SUV-150B measurements at 340 nm. Period A is shown in greater detail in Figure 5.7.7.*

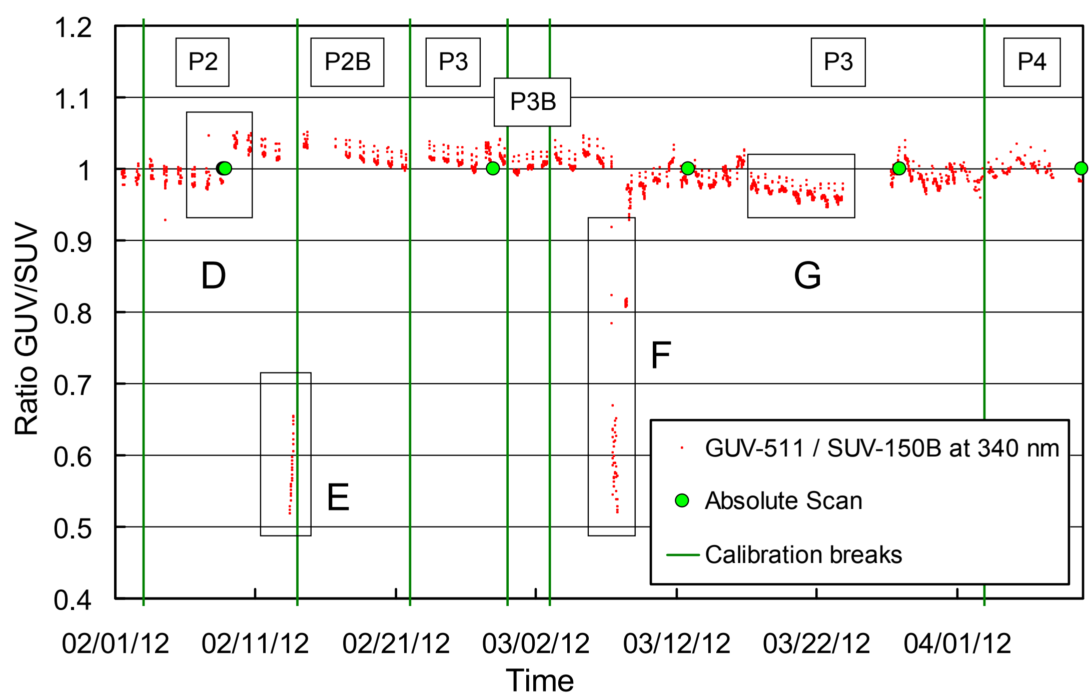

Figure 5.7.7. *Close-up of Period A of Figure 5.7.6.*

5.7.3. Wavelength Calibration

Wavelength stability of the system was monitored with the internal mercury lamp. Figure 5.7.8 shows the differences in the wavelength offset of the 296.73 nm mercury line between pairs of consecutive wavelength scans for the period 1/1/12 – 12/19/12. 323 scans were evaluated. For 98.8% of the scans is the difference in the wavelength offset to neighboring scans less than ±0.0055 nm. Minimum and maximum shifts between consecutive scans were -0.023 and +0.029 nm, respectively. These comparatively large changes related to the system shutdown for releveling the host building. Note that this stability is a factor of 10 better than the wavelength stability of SUV-100 spectroradiometers used at other sites. The SUV-150B has a superior wavelength stability due to the use of high-resolution optical encoders that are used in a closed feedback loop with the stepper-motor controllers.

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 Fraunhofer-line correlation method used for Version 2 processing (*Bernhard et al., 2004*; see also Section 4.2.2.2). Due to the good wavelength stability of the system, only one correction function had to be applied for the entire reporting period (Figure 5.7.9). Since the position of the monochromator's gratings is determined by optical encoders, irregularities in the monochromator drive are inconsequential. This explains the smoothness of the functions. Most of the variations observed are artifacts of the correlation algorithm, which has an uncertainty of about 0.015 nm.

After data was corrected using this function, the wavelength accuracy of all noontime scans was verified with the "Version 2" Fraunhofer-line correlation algorithm. Results are shown in Figure 5.7.10. Residual wavelength errors tend to be smaller than zero before the Green House service and larger thereafter. These small biases were removed as part of the processing of Version 2 data.

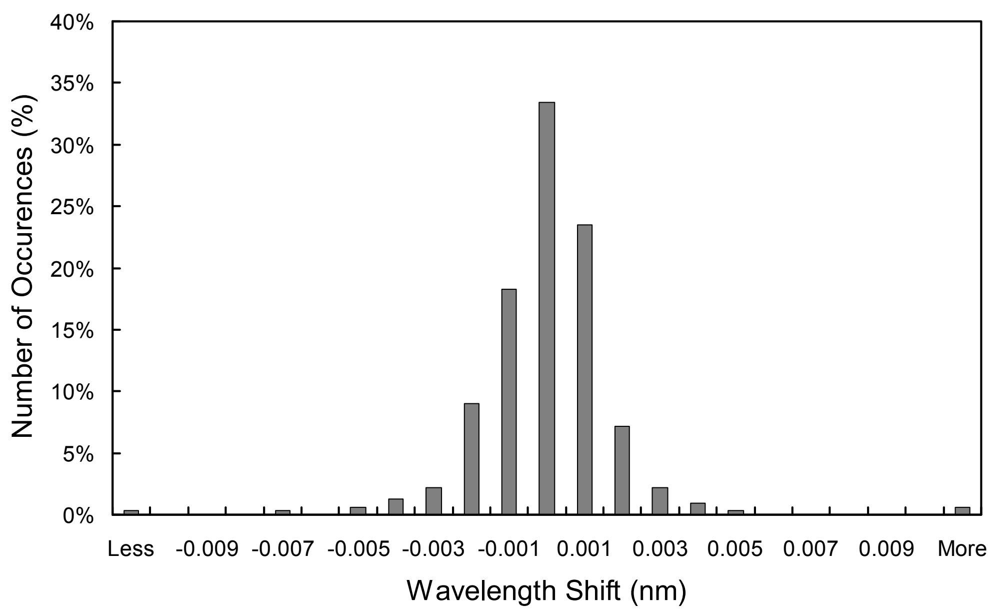

Figure 5.7.8. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans for the period 1/1/12 – 12/19/12. The labels of the horizontal axis give the center wavelength shift for each column. The 0-nm histogram column covers the range from -0.0005 to +0.0005 nm. "Less" means shifts smaller than -0.0105 nm; "more" means shifts larger than 0.0105 nm.*

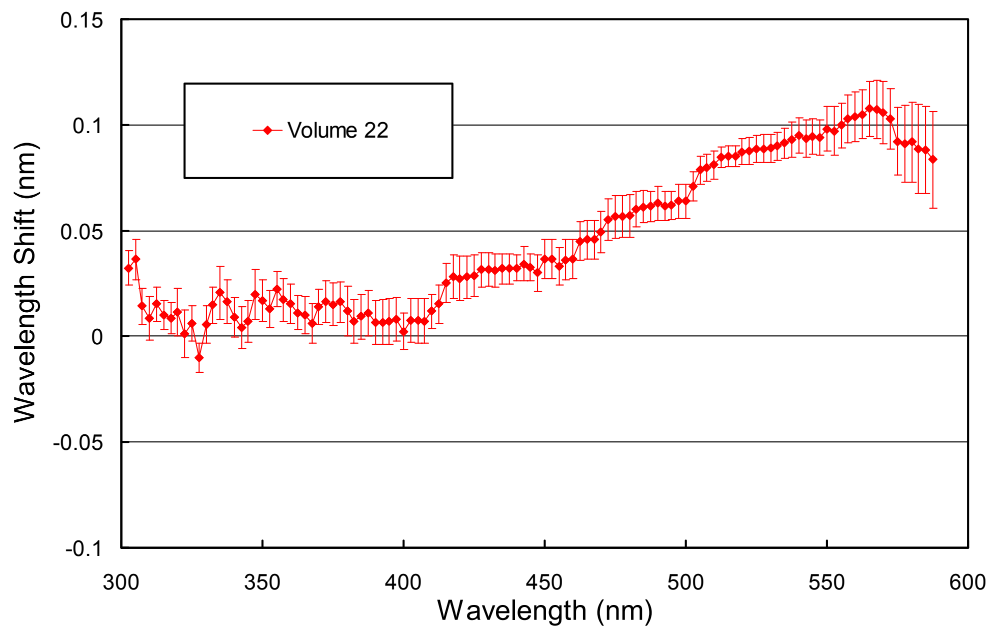

Figure 5.7.9. *Monochromator non-linearity correction functions of Volume 22 data.*

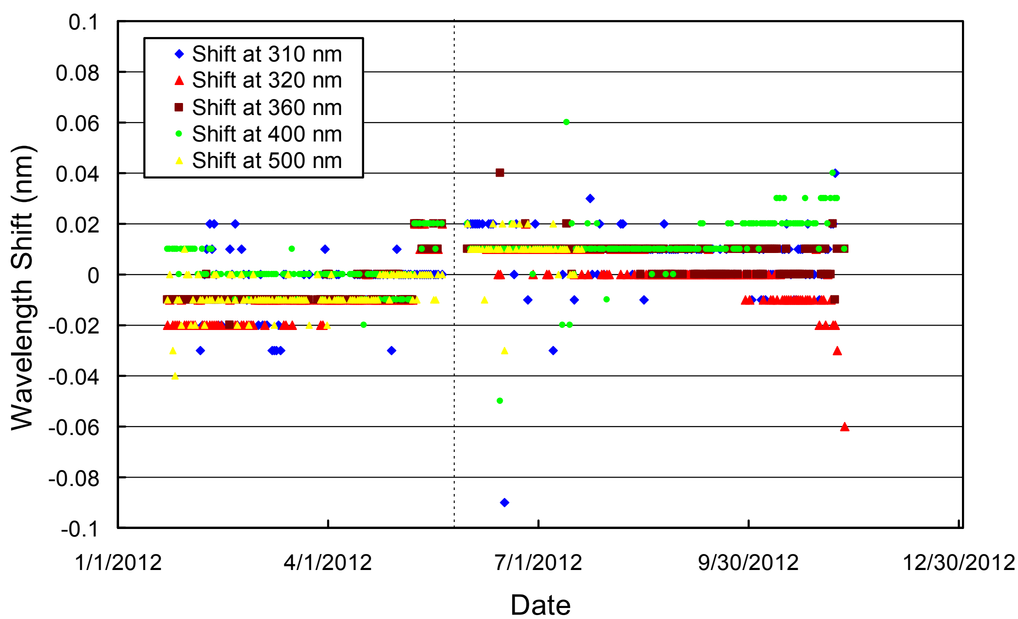

Figure 5.7.10. *Wavelength accuracy check of final Volume 22 data at five wavelengths in the UV and visible by means of Fraunhofer-line correlation. All noontime measurement have been evaluated. The vertical broken line indicates the day when the Green House was releveled.*

5.7.4. Missing Data

A total of 17211 scans are part of the Summit Volume 22 dataset. Missing periods are summarized in Table 5.7.2.

Table 5.7.2. Incomplete days in the Summit Volume 22 dataset.

Period	Reason
02/15/12 - 02/16/12	Software “froze“ after failure of lamp power supply fuse
02/22/12	Replacement of lamp power supply fuse
03/24/12 - 03/26/12	Software error
04/08/12	Software error
05/22/12 - 05/30/12	System off line for releveling of Green House
10/02/12	Software error
11/09/12	Software error
11/09/12	Software error

5.7.5. GUV Data

The GUV-511 radiometer, which is installed next to the SUV-150B, was calibrated against Version 2[1] SUV-150B measurements following the procedure outlined in Section 4.3.1. From the calibrated measurements, data products were calculated (Section 4.3.2). Figure 5.7.11 shows a comparison of GUV-511 and SUV-150B erythemal irradiance for the Volume 22 period. For solar zenith angles (SZA) smaller than 80°, measurements of the two instruments agree to within ±1.8% (±1σ). The ratio of measurements of the two instruments has a larger variability during the spring than fall. This has several reasons. First, the calibration of the SUV-150B typically requires more adjustments earlier in the year, leading to small (<2%) step changes. Second, before the Green House was serviced, instruments were not level and even though the effect was largely removed as part of processing of Version 2 data, some artifacts remain. Third, measurements were sometimes disturbed by heavy equipment close to collectors of the SUV-150B and GUV instruments. We advise data users to use SUV-150B rather than GUV-511 data whenever possible, in particular for low-Sun conditions.

Figure 5.7.12 shows a comparison of total ozone measurements from the GUV-511, SUV-150B Version 2 data and the Ozone Monitoring Instrument (OMI). The SUV-150B and GUV-511 data sets agree well with OMI observations. The average ratio SUV/OMI is 1.013, and the standard deviation of the ratio is 2.7%. This good agreement—even at large SZAs—is achieved by using ozone profiles in the inversion algorithm, which were measured at Summit by NOAA’s Global Monitoring Division. The average ratio GUV / OMI for SZAs smaller than 80° is 0.991 and the standard deviation of the ratio is 3.2%. As the SZA gets larger, GUV measurements tend to get smaller relative to OMI and SUV-150B data. For solar zenith angles larger than 80°, measurements of the GUV’s 305 nm channel are close to the detection limit. GUV ozone data at large SZAs become unreliable and should not be used.

[1] Usually GUV data are calibrated against Version 0 SUV-150B data. We decided to calibrated Volume 22 GUV data against Version 2 SUV-150B data because these data have been corrected for the change in the tilt of the Green House where both instruments are located.

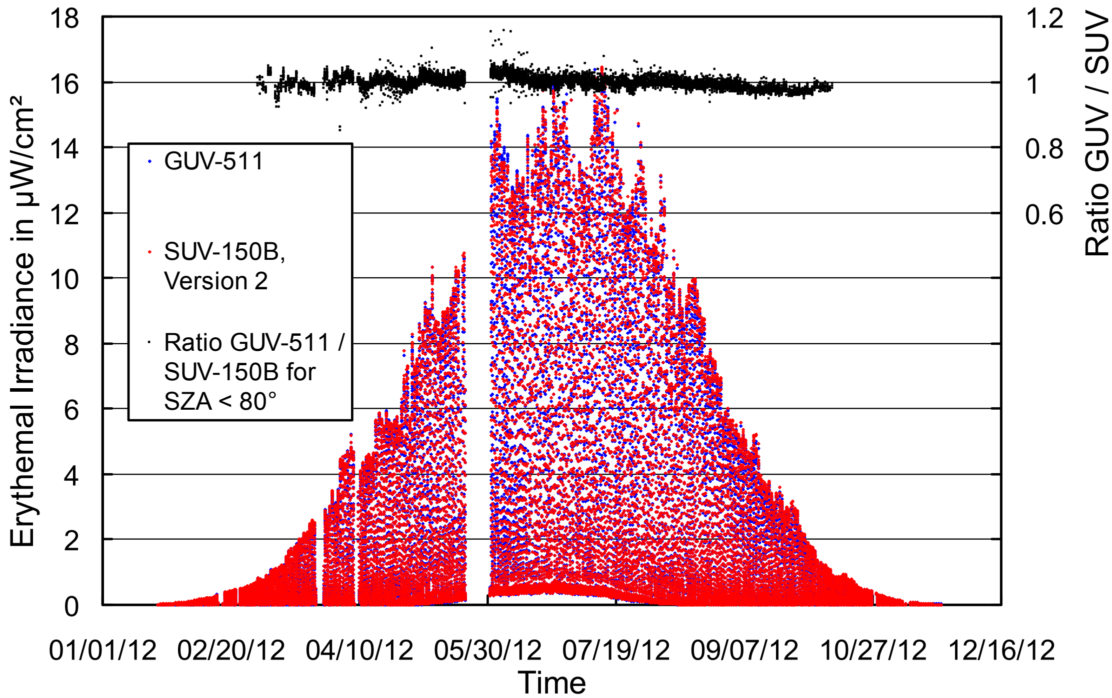

Figure 5.7.11. *Comparison of erythemal irradiance measured by the SUV-150B spectroradiometer and the GUV-511 radiometer. SUV-150B measurements are based on "Version 2" (cosine-error corrected) data.*

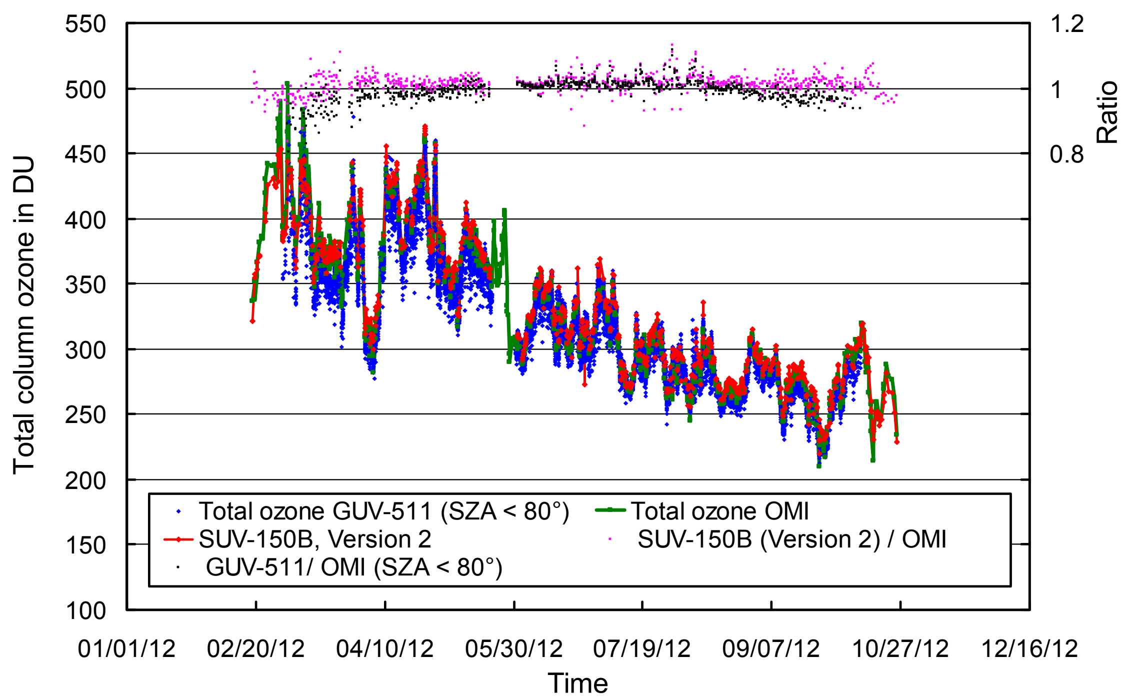

Figure 5.7.12. *Comparison of total column ozone measurements from GUV-511, SUV-150B (Version 2 data), and OMI. GUV-511 measurements are plotted in 15 minute intervals. For calculating the ratio of data sets, only measurements concurrent with the OMI overpass were evaluated.*