## 5.7. Summit, Greenland (01/20/11 – 11/24/11)

This section describes quality control of "Volume 21" solar data recorded by the SUV-150B spectroradiometer at Summit Camp, Greenland, between 01/20/11 and 11/24/11.

Changes in responsivity observed during the last years continued in 2011. 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%.

Several calibration lamps were inadvertently moved in their holders by research associates at Summit during the reporting period, changing their irradiance at the instrument's collector. All on-site standards were recalibrated in November 2011 using the traveling standards 200W017 and 200W038. The time when the lamp's bulbs were moved could be determined by examining the time records of instrument calibrations.

The "Green House" where the instrument is located tilted by about 2° over the reporting period. This change is larger than the adjustment range of the SUV-150B's collector. At the end of 2011, the collector was out of alignment by 0.7° in northern direction and 0.5° in western direction. This leveling error caused variations in solar measurements with respect to the solar azimuth angle. The systematic error was reduced as part of the Version 2 cosine error correction. Version 0 data described in this report remain affected by this error.

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. Affected scans were not removed from the Version 0 dataset, however, they were flagged in the Version 2 SUV-150B dataset (available at uv.biospherical.com\Version2).

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 17552 scans are part of the Summit Volume 21 dataset.

### 5.7.1. Irradiance Calibration

The on-site irradiance standards used during the reporting period were the lamps 200W027, 200W030, and 200W043. Lamps 200W017 and 200W038 served as traveling standards.

Calibration history of on-site standards 200W027, 200W030, and 200W043
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 the traveling standards 200W017 and 200W038. This calibration was used for solar data of the reporting period.

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 to process solar data of the period 07/30/11 – 11/24/11.

Lamp 200W043 was calibrated on 6/2/07 against a set of four FEL lamps using the same procedure as that described for lamp 200W017 below. This calibration was used to process solar data of the period 01/20/11 – 06/18/11. The lamp was recalibrated again in November 2011 against the traveling standards 200W017 and 200W038. This calibration was used to process solar data of the period 07/01/11 – 11/24/11.

Calibration history of traveling standards 200W017 and 200W038

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. Data of certificates issued by the CUCF were converted to the NIST1990 scale before the calibration was transferred to the lamp.

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 5.7.1 shows a comparison of lamps 200W017, 200W027, 200W030, 200W038, and 200W043 performed at Summit in November 2011. All measurements are consistent to within ±1.0%. The calibrations of the three site standards are consistent with the calibrations of the traveling standards to within ±1%. The good agreement between lamps 200W027, 200W030, and 200W043 can be expected because these lamps were calibrated consistently using the same raw data as used to produce Figure 5.7.1. Of note, the travel standards 200W017 and 200W038 have independent calibrations and burn times. The good agreement between the two lamps gives confidence in their calibrations.

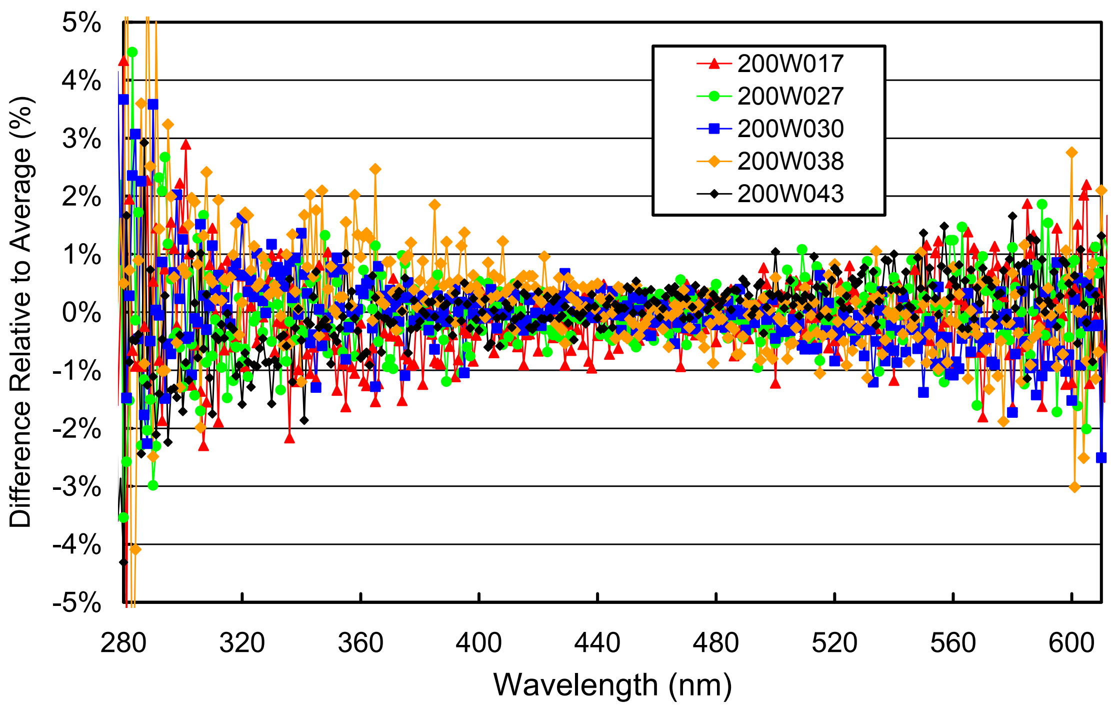


**Figure 5.7.1.** *Comparison of lamps 200W017, 200W027, 200W030, 200W038, and 200W043. Data were collected at Summit on 3-4 November 2011.*

### 5.7.2. Instrument Stability

The temporal stability of the spectroradiometer is monitored with bi-weekly calibrations utilizing site irradiance standards; daily response scans of the internal irradiance reference lamp; measurements of filtered photodiodes integral to the instrument's integrating sphere; and by comparison with the co-located GUV-511 radiometer and results from a radiative transfer model. Daily response scans help to uncover instabilities related to monochromator and PMT but cannot be used to track changes in the instrument's cosine collector (integrating sphere + PTFE diffuser). In contrast, the sphere's photodetectors are only sensitive to changes in the cosine collector and are not affected by possible drifts of other system components such as the optical fiber or the monochromator.

Figure 5.7.2 shows changes in TSI readings and PMT currents at 320 and 400 nm, derived from response scans performed between 2/14/06 and 12/31/11. 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. The relative change of the second lamp's intensity as recorded by the TSI between 9/2/09 and 12/31/11 is similar to that of the original lamp. The trend of PMT currents follows that of the TSI measurements but superimposed on the general trend is a sinusoidal variation with a periodicity of one year. 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 during data processing.

To account for changes of the system's sphere-throughput and PMT-sensitivity, the reporting period was broken into 20 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 these irradiance spectra relative to the spectrum applied in period P1 are shown in Figures 5.7.3. The ratios for the smoothed datasets (which were used for the calibration of solar measurements) are indicated by thick lines.

The quality of calibrated solar measurements of the SUV-150B was further assessed by comparison with the GUV-511 radiometer. Figures 5.7.4 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 agree to within ±5%. The standard deviation of the ratio is 1.9%. Step-changes at times when the SUV's calibration was changed are typically smaller than 1%.

**Table 5.7.1. Calibration periods for Summit Volumes 21.**

| Period name | Period range | Number of absolute scans | Remarks |
|---|---|---|---|
| P1 | 01/01/11 – 02/17/11 | 2 | |
| P1B | 02/18/11 – 02/23/11 | 0 | Average of P1 and P2 |
| P2 | 02/24/11 – 03/02/11 | 1 | |
| P3 | 03/03/11 – 03/13/11 | 1 | |
| P3A | 03/14/11 – 03/17/11 | 0 | Scaled from P3 and P4 |
| P3B | 03/18/11 – 03/20/11 | 0 | Scaled from P3 and P4 |
| P3C | 03/21/11 – 03/24/11 | 0 | Scaled from P3 and P4 |
| P3D | 03/25/11 – 03/28/11 | 0 | Scaled from P3 and P4 |
| P3E | 03/29/11 – 04/01/11 | 0 | Scaled from P3 and P4 |
| P3F | 04/02/11 – 04/04/11 | 0 | Scaled from P3 and P4 |
| P3G | 04/05/11 – 04/08/11 | 0 | Scaled from P3 and P4 |
| P4 | 04/09/11 – 04/14/11 | 1 | |
| P4B | 04/15/11 – 04/18/11 | 0 | Average of P4 and P5 |
| P5 | 04/19/11 – 06/30/11 | 3 | |
| P6 | 07/01/11 – 07/22/11 | 0 | Average of P5 and P7 |
| P7 | 07/23/11 – 08/05/11 | 1 | |
| P8 | 08/06/11 – 09/01/11 | 0 | Average of P7 and P9 |
| P9 | 09/02/11 – 09/15/11 | 1 | |
| P10 | 09/16/11 – 10/15/11 | 0 | Average of P9 and P11 |
| P11 | 10/16/11 – 12/31/11 | 8 | |

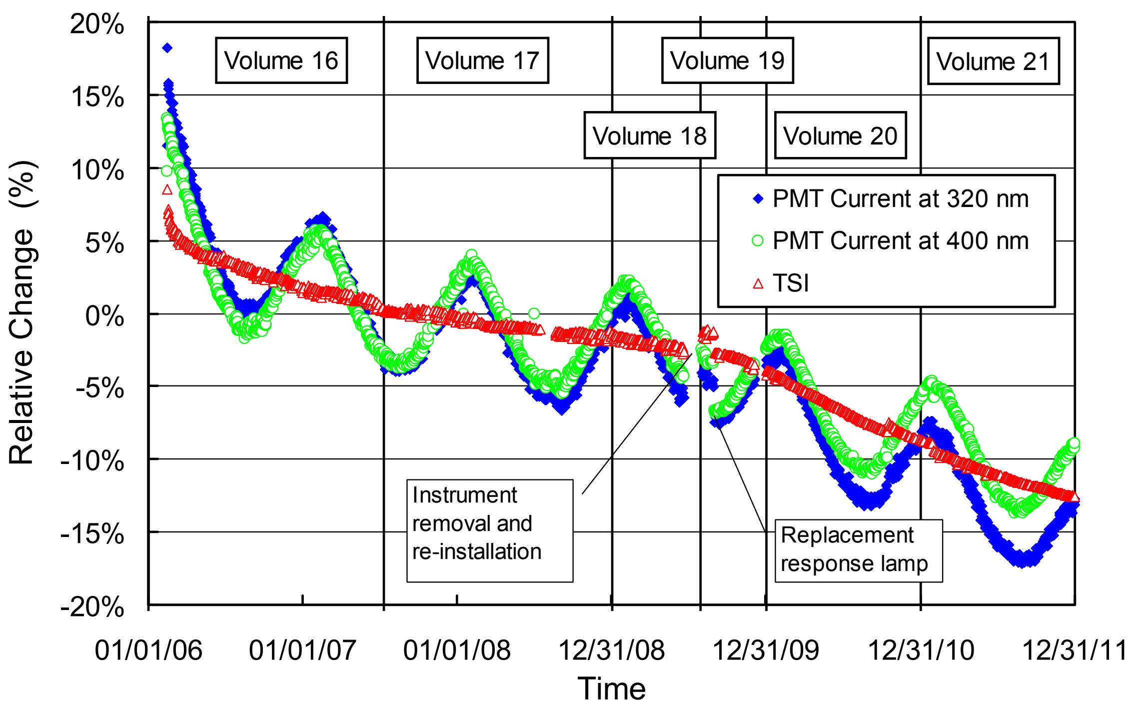


**Figure 5.7.2.** *Time-series of TSI signal and PMT currents at 320 and 400 nm during measurements of the internal reference lamp performed at Summit between 2/15/06 and 12/31/11. Data from 9/2/10 (date of response lamp replacement) were scaled to downward to fit into the existing pattern.*

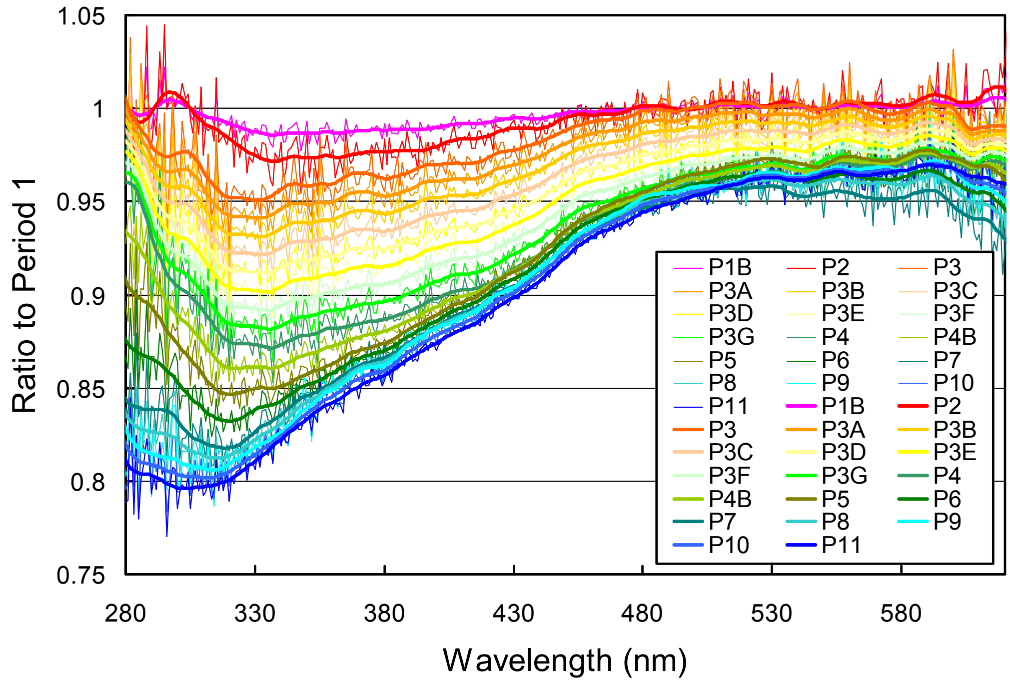


**Figure 5.7.3.** *Ratios of irradiance assigned to the internal reference lamp in Periods P1B – P11, referenced to the irradiance of Period P1. Thick lines indicate ratios of the smoothed irradiance spectra used for the calibration of solar measurements.*

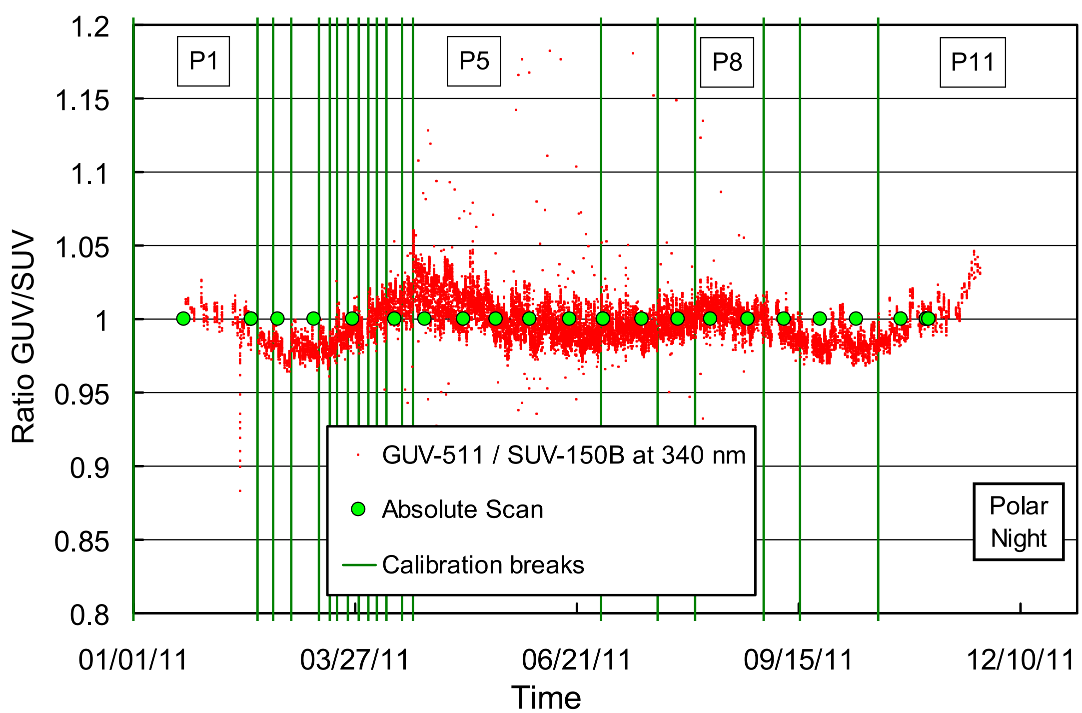


**Figure 5.7.4.** *Ratios of GUV-511 and SUV-150B measurements at 340 nm.*

### 5.7.3. Wavelength Calibration

Wavelength stability of the system was monitored with the internal mercury lamp. Figure 5.7.5 shows the differences in the wavelength offset of the 296.73 nm mercury line between pairs of consecutive wavelength scans for the period 1/1/11 –12/31/11. 336 scans were evaluated. For 95.8% 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 -0.022 and +0.021 nm, respectively. Note that this stability is a factor of 10 better than the wavelength stability of SUV-100 spectroradiometers. 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. In Figure 5.7.6, the correction function for data of the Volume 21 period is shown in comparison to the functions established for the Volume 19 and 20 periods. 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 5.7.7 for four UV wavelengths and one wavelength in the visible. Residual shifts are typically smaller than ±0.02 nm.

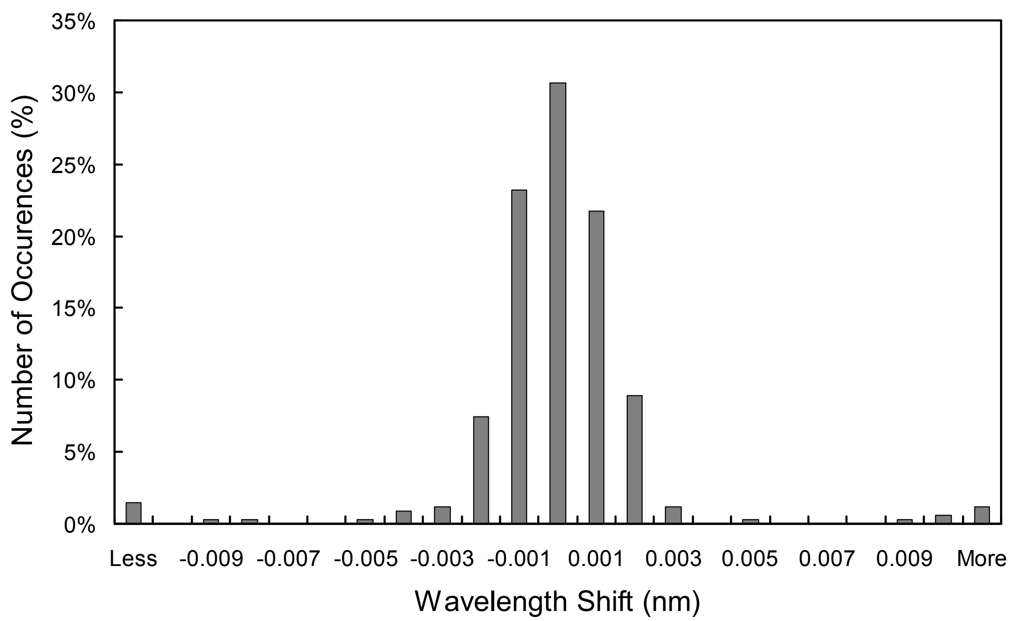


**Figure 5.7.5.** *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans for the period 1/1/11 – 12/31/11. The labels of the horizontal axis give the center wavelength shift for each column. The 0-nm histogram column covers the range from -0.0005 to +0.0005 nm. "Less" means shifts smaller than -0.0105 nm; "more" means shifts larger than 0.0105 nm.*

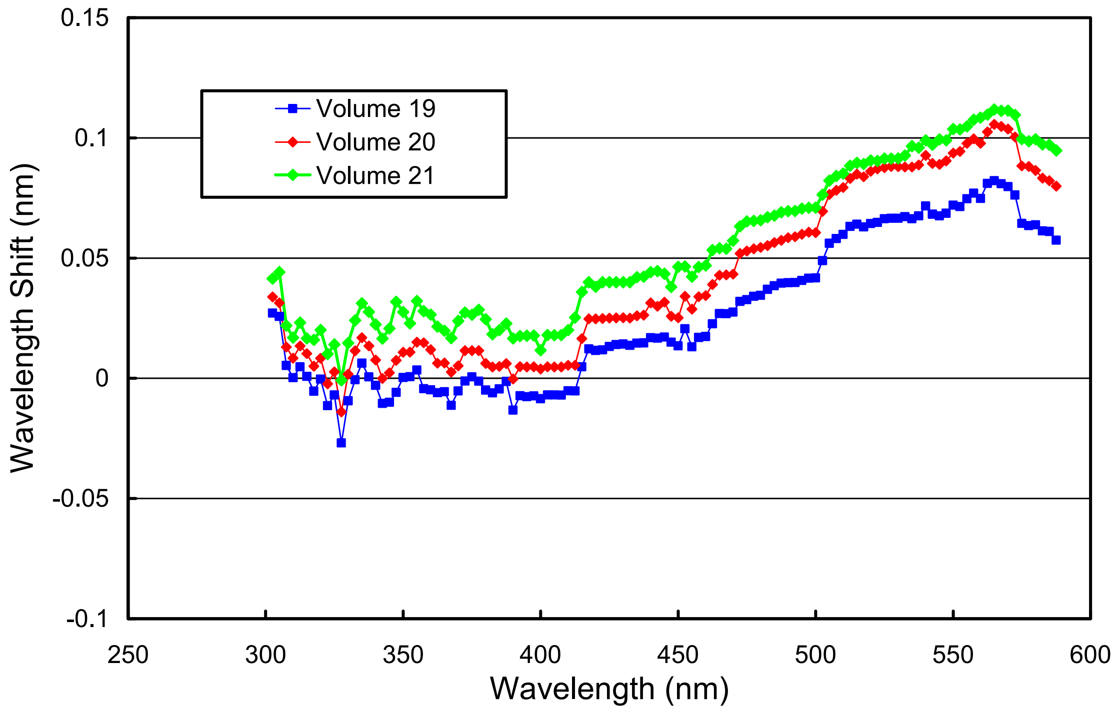


**Figure 5.7.6.** *Monochromator non-linearity correction functions for Volume 19 – 21 periods at Summit.*

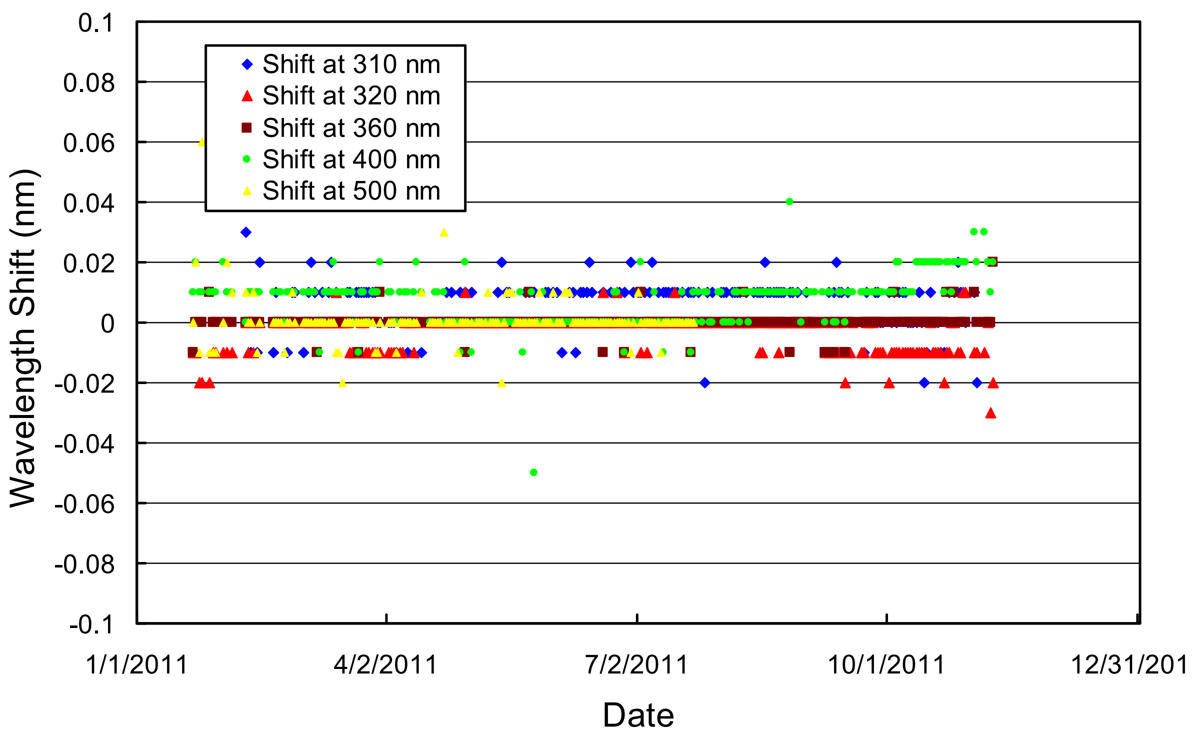


**Figure 5.7.7.** *Wavelength accuracy check of final Volume 21 data at five wavelengths in the UV and visible by means of Fraunhofer-line correlation. All noontime measurement have been evaluated.*

### 5.7.4. Missing Data

A total of 17552 scans are part of the Summit Volume 21 dataset. Missing periods are summarized in Table 5.7.2.

**Table 5.7.2. Incomplete days in the Summit Volume 21 dataset.**

| Period | Reason |
|---|---|
| 01/25/11 - 01/26/11 | Software error |
| 01/30/11 - 01/31/11 | Software error |
| 02/05/11 - 02/08/11 | Software error |
| 02/15/11 - 02/18/11 | unknown |
| 02/28/11 - 03/01/11 | Software error |
| 03/31/11 - 04/01/11 | unknown |
| 04/16/11 | Calibration |
| 08/31/11 | Software updates |
| 09/05/11 - 09/06/11 | Software error |
| 09/19/11 - 09/20/11 | Software error |
| 09/30/11 | Hardware error (unresponsive electrometer) |
| 10/30/11 - 10/31/11 | Software error |
| 11/03/11 - 11/04/11 | Calibrations (comparison with traveling standards) |
| 11/13/11 - 11/14/11 | Hardware error (unresponsive electrometer) |
| 11/13/11 - 11/14/11 | Hardware error (unresponsive electrometer) |

### 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 5.7.8 shows a comparison of GUV-511 and SUV-150B erythemal irradiance for the Volume 21 period. For solar zenith angles (SZA) smaller than 80°, measurements of the two instruments agree to within ±2.2% (±1σ). The ratio tends to be larger than one between 3/15/11 and 5/20/11. This bias has likely two reasons. First, the sensitivity of the GUV's 320 nm channel has drifted by about 5% over the year. Measurements in the spring tend to be high by 1-2.5% and measurements in the fall are low by the same amount. This drift has not been corrected. Second, model calculations suggest that SUV-150B measurements are somewhat (~2%) biased low in spring. However, it cannot be ruled out that the UV irradiance at Summit was actually somewhat suppressed in spring due to the effect of aerosols (Arctic haze). We advise data users to use SUV-150B rather than GUV-511 data whenever possible, in particular for low-Sun conditions.

Figure 5.7.9 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 2.9%. 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 0.995 and the standard deviation of the ratio is 2.0%. 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 21 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.

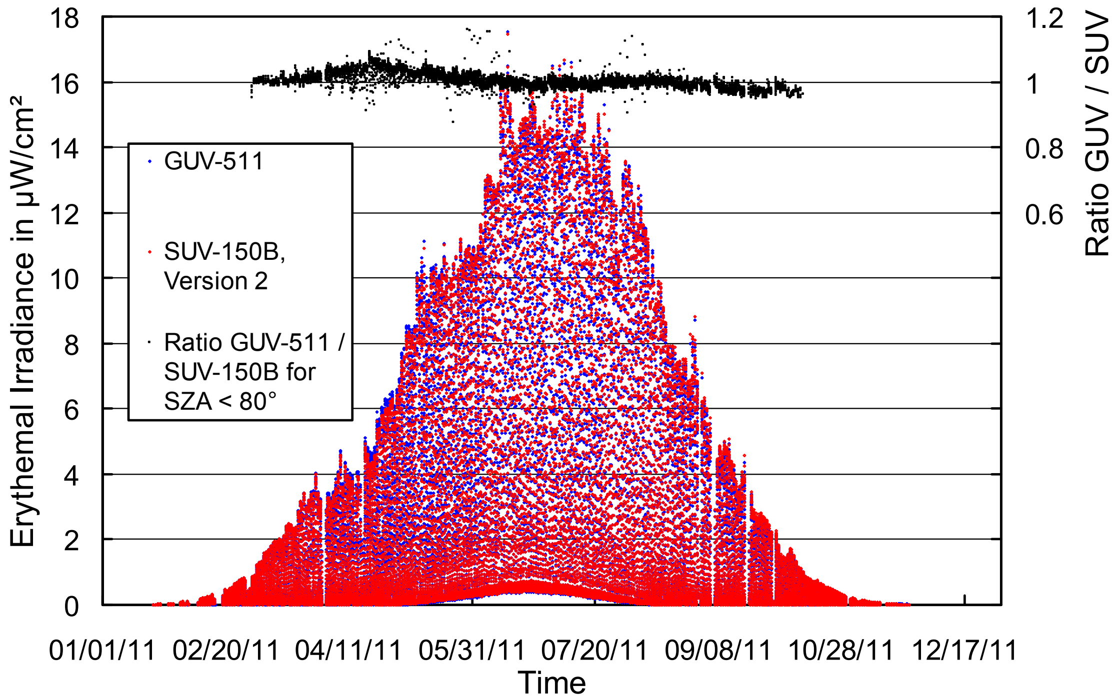


**Figure 5.7.8.** *Comparison of erythemal irradiance measured by the SUV-150B spectroradiometer and the GUV-511 radiometer. SUV-150B measurements are based on "Version 2" (cosine-error corrected) data.*

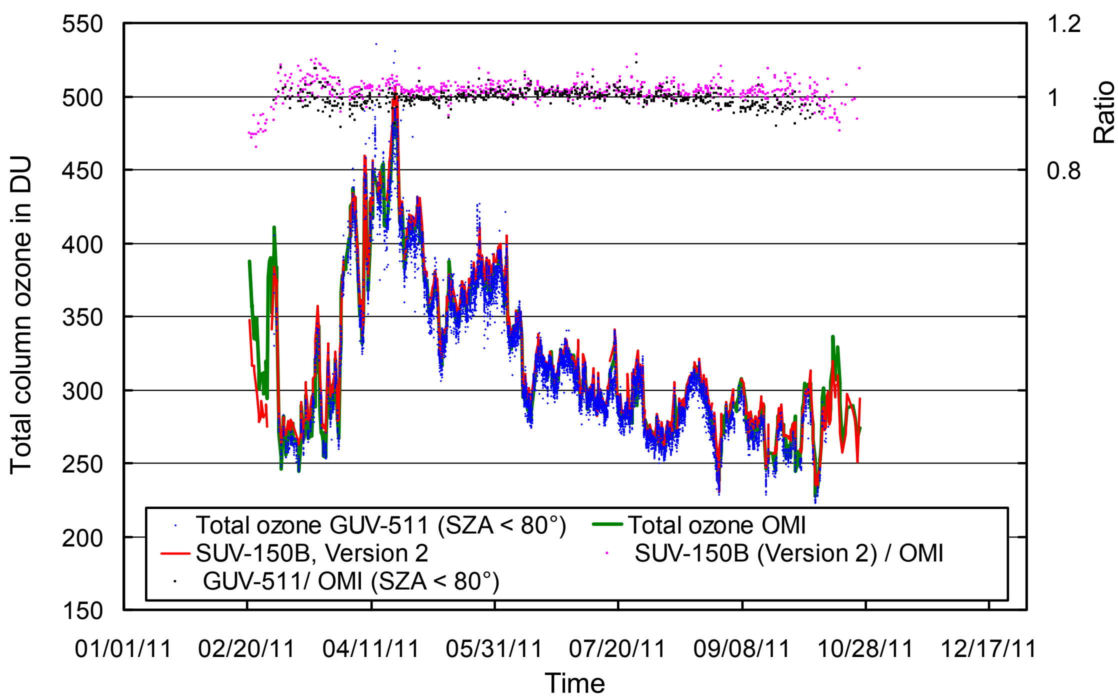


**Figure 5.7.9.** *Comparison of total column ozone measurements from GUV-511, SUV-150B (Version 2 data), and OMI. GUV-511 measurements are plotted in 15 minute intervals. For calculating the ratio of data sets, only measurements concurrent with the OMI overpass were evaluated.*