5.7. Summit, Greenland (8/15/04 – 5/17/05)

This section describes quality control of solar data recorded by the SUV-150B spectroradiometer at Summit Camp, Greenland, between 8/15/04 and 5/17/05. These data comprise the first measurements of solar UV irradiance at this recently established network site. The instrument was installed between 7/26/04 and 8/17/04. Opening calibrations took place between 8/11/04 and 8/16/04. Closing calibrations were performed on 5/18/05.

Large snow accumulation during the winter of 2004/2005 required relocation of the building in which the instrument is installed. To accommodate this work, the spectroradiometer had to be temporarily removed in May 2005. It was reinstalled in July 2005. No solar data are available for the period 5/18/05 – 7/30/05.

This is the first operational installation of a SUV-150B spectroradiometer. Getting a new and complex system at a new site up and running is always a challenge. The instrument provided data of good quality but some instrument problems led to data loss. The following problems affected system performance during the reporting period.

Drift of instrument responsivity due to change of collector throughput
The instrument's responsivity changed by a large amount during the reporting period. This drift was caused by rapid degradation of the internal coating of the integrating sphere that is part of the instrument's fore optics. This degradation was much larger than expected. In response to the problem, the original integrating sphere, which was coated with Barium sulfate, was replaced in August 2005 by a new sphere that is lined with solid shells of a Polytetrafluorethylene (PTFE) material. Preliminary data analysis indicates that the throughput of the new sphere is stable. Since the rate of degradation of the original sphere was monotonous and predictable, the drift could be corrected by frequently adjusting the instrument's calibration. Comparison of measurements of the SUV-150B with data from the collocated GUV-511 radiometer indicates that drift-related uncertainties of final solar data are smaller than ±4%. The good quality of data was further confirmed by comparison with results of a radiative transfer model.

Intermittent contact in response lamp circuit
The internal reference lamp did not work between 10/20/04 and 11/3/04 due to a missing cable-securing screw. The problem also caused the software to hang when it tried to switch on the lamp. This problem resulted in loss of solar data on two days. The intermittent connection was repaired on 11/3/04. The internal lamp was also replaced on this day.

Mercury lamp power supply failure
The mercury lamp power supply electronics failed on 1/26/05, causing the lamp to stay on during solar scans. Solar spectra measured between 1/26/05 and 2/2/05 have the spectrum of the mercury lamp superimposed and had to be discarded. The lamp was manually switched off on 2/2/05 and new electronics were installed on 3/12/05. No scans of the mercury lamp could be performed between 1/26/05 and 3/12/05 due to this failure. This has little consequence on published data due to the exceptionally good wavelength stability of the system.

Communication problems between computer and data acquisition components
On several occasions, the computer was not able to communicate with a data acquisition unit and the electrometer measuring the PMT photocurrent. The problem required manual cycling of the power to the devices, which resulted in occasional loss of data.

Software problems
The SUV-150B system control software halted on several occasions. In addition, data scans were sometimes labeled with an incorrect filename. As a consequence of the latter event, date and time encoded into the filename did not match the actual date, and data were partly overwritten. These problems caused some data loss.

A total of 9335 scans are part of the published Summit Volume 14 dataset. About 22% of all scans that could have been recorded were lost due to the technical problems summarized above. A more detailed breakdown of missing scans can be found in Section 5.7.4.

The Eppley PSP pyranometer (S/N 32760F3) installed next to the SUV-150B was calibrated by Eppley Laboratory on 4/8/2004.

5.7.1. Irradiance Calibration

The irradiance standards used during the reporting period were the lamps 200W027 and 200W030. Both lamps were calibrated by Optronic Laboratories on 3/28/01 and have only been used for a few times since. Lamp 200W017 was used as traveling standard at the end of the season. This lamp was calibrated by Optronic Laboratories on 3/19/01.

Figure 5.7.1 shows a comparison of lamps 200W027 and 200W017 with 200W030 during different times. Lamps 200W027 and 200W030 agreed with each other to within ±2% during the season opening calibration event (8/11/04 – 8/16/04) and on 11/6/04 and 1/29/04. Results obtained during the calibration session at the end of the season (5/18/05) show larger discrepancies in the UV. The wavelength dependent differences are likely caused by instability of the instrument's integrating sphere rather than real differences in the lamp's calibrations. Similar wavelength dependent changes in sphere throughput have been noticed previously and prompted replacement of the sphere at the beginning of the Volume 15 season.

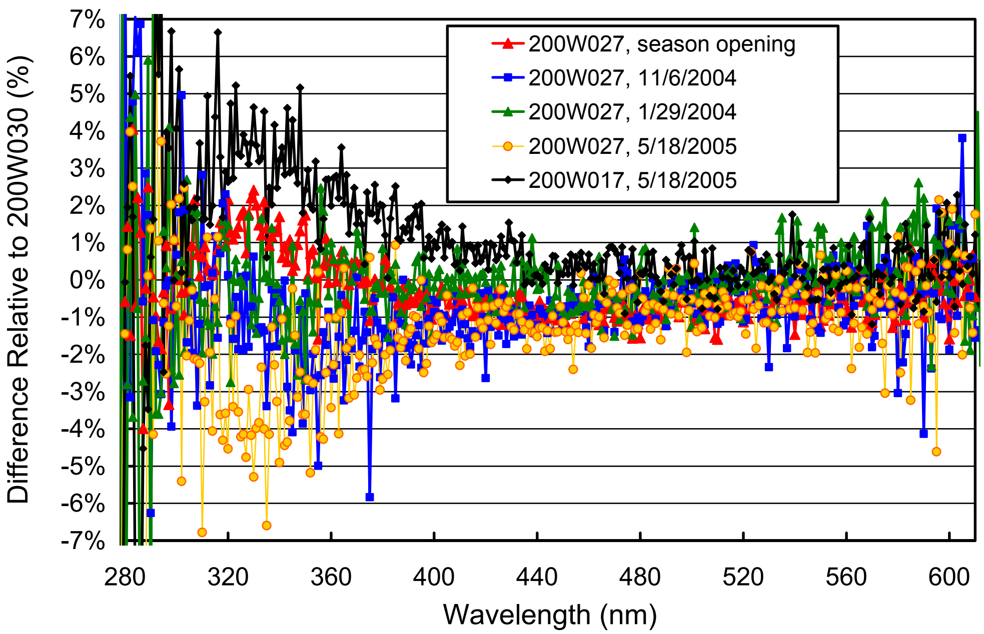

Figure 5.7.1. *Comparison of lamps 200W027 and 200W017 with lamp 200W030 at Summit.*

5.7.2. Instrument Stability

The stability of the spectroradiometer over time is primarily monitored with bi-weekly calibrations utilizing site irradiance standards and daily response scans of the internal irradiance reference lamp. The daily response scans help to uncover instabilities related to monochromator and PMT but cannot be used to track changes in the instrument's fore optics. The TSI sensor is used for tracking the stability of the internal lamp.

Figure 5.7.2 shows the changes in TSI readings and PMT currents at 320 and 400 nm, derived from response scans performed between 8/15/04 and 10/19/04. All parameters are stable to within ±1.5%, indicating good performance of monochromator and PMT. On 10/20/04, the response lamp failed due to an intermitted circuit. No scans of the internal lamp are available between 10/20/04 and 11/1/04. The response scan performed on 10/19/04 was used to calibrate the system for the period 10/20/04 – 11/2/04. This procedure is acceptable due to the good stability of the monochromator and PMT.

Figure 5.7.3 shows changes in TSI readings and PMT currents at 320 and 400 nm for the period 11/2/04 – 5/12/05. This is the period following the installation of the new lamp. TSI measurements during this period changed by less than 1%. Measurements of the PMT changed by ±4%. These changes were corrected by using the information from the daily response scans.

As note previously, measurements of the internal lamp cannot be used to detect changes in the throughput of the instrument's fore optics. Absolute scans indicated that the overall responsivity of the system decreased substantially between the start of the season and November 2004. This change was caused by a degradation of the integrating sphere's coating. In response to this problem, a sphere with a different material was developed and installed in August 2005. To correct for the loss in sensitivity, the instrument's calibration for 2004 was broken into 12 periods (Table 5.7.1.)

Figure 5.7.4 presents ratios of irradiance spectra applied to the internal lamp during periods P 2 – P 12 (August 2004 – October 2004), referenced to the spectrum for Period P 1. The figure shows that the spectra changed by about 35% in the UV-B, but less than 4% in the visible. The change is very monotonous over time, allowing to correct the drift with reasonable uncertainty. Differences between consecutive calibration functions are typically less than 3%, which is also the additional uncertainty in solar data caused by the drift.

Figure 5.7.5 shows similar ratios of irradiance spectra applied to the internal lamp during periods P 15 – P 19 (November 2004 – May 2005), referenced to the spectrum for Period P 14. Interestingly, the ratios get smaller over time, indicating that the instrument responsivity increased. Thus, part of the loss in responsivity observed during the first three month of operation was reversed during the rest of the season. We do not have an explanation for this behavior. The change was monotonous also during this period and solar data could be corrected with little additional uncertainty.

Table 5.7.1 Calibration periods for Summit Volume 14.

Period name	Period range	Number of Absolute scans	Remarks
P 1	01/01/04 - 08/28/04	5	
P 2	08/29/04 - 09/01/04	0	Interpolated from Period P 1, P 6
P 3	09/02/04 - 09/05/04	0	Interpolated from Period P 1, P 6
P 4	09/06/04 - 09/09/04	0	Interpolated from Period P 1, P 6
P 5	09/10/04 - 09/13/04	0	Interpolated from Period P 1, P 6
P 6	09/14/04 - 09/22/04	1	
P 7	09/23/04 - 09/28/04	0	Interpolated from Period P 7, P 8
P 8	09/29/04 - 10/02/04	1	
P 9	10/03/04 - 10/09/04	0	Interpolated from Period P 8, P 10
P 10	10/10/04 - 10/16/04	1	
P 11	10/17/04 - 11/02/04	1	
P 12	11/03/04 - 12/31/04	2	
P 14	01/01/05 - 02/05/05	1	
P 14B	02/06/05 - 02/14/05	0	Interpolated from Period P 14, P 15
P 15	02/15/05 - 02/20/05	2	
P 15B	02/21/05 - 02/24/05	0	Interpolated from Period P 15, P 16
P 15C	02/25/05 - 02/28/05	0	Interpolated from Period P 15, P 16
P 15D	03/01/05 - 03/04/05	0	Interpolated from Period P 15, P 16
P 15E	03/05/05 - 03/08/05	0	Interpolated from Period P 15, P 16
P 15F	03/09/05 - 03/12/05	0	Interpolated from Period P 15, P 16
P 15G	03/13/05 - 03/16/05	0	Interpolated from Period P 15, P 16
P 15H	03/17/05 - 03/20/05	0	Interpolated from Period P 15, P 16
P 16	03/21/05 - 03/24/05	1	
P 16B	03/25/05 - 03/31/05	0	Interpolated from Period P 16, P 17
P 17	04/01/05 - 04/15/05	1	
P 18	04/16/05 - 05/09/05	2	
P 19	05/10/05 - 05/18/05	1	

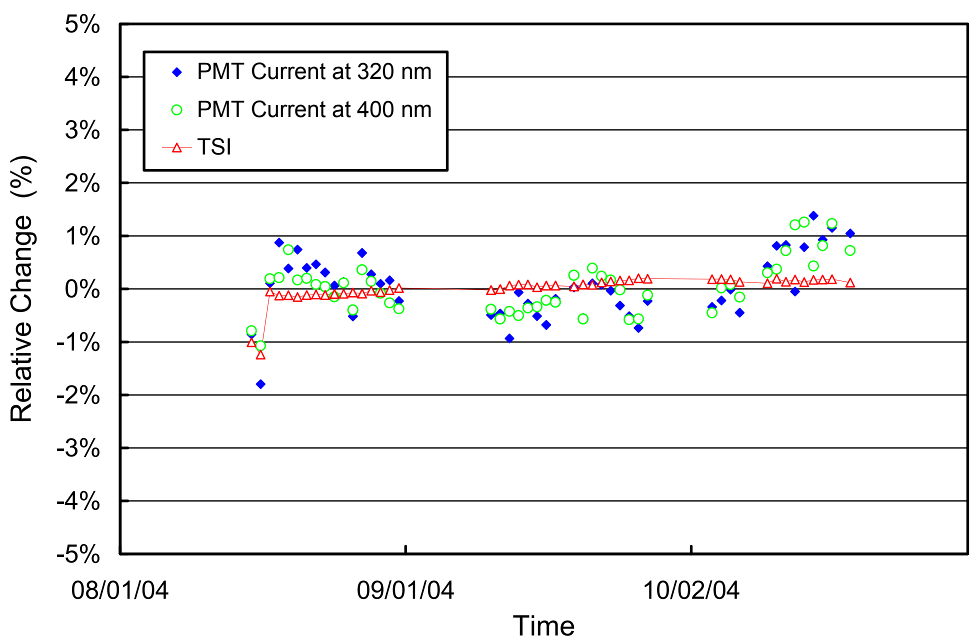

Figure 5.7.2. *Time-series of TSI signal and PMT currents at 320 and 400 nm during measurements of the internal reference lamp performed at Summit between 8/15/04 and 10/19/04. On 10/20/04, the response lamp stopped functioning due to an intermitted circuit.*

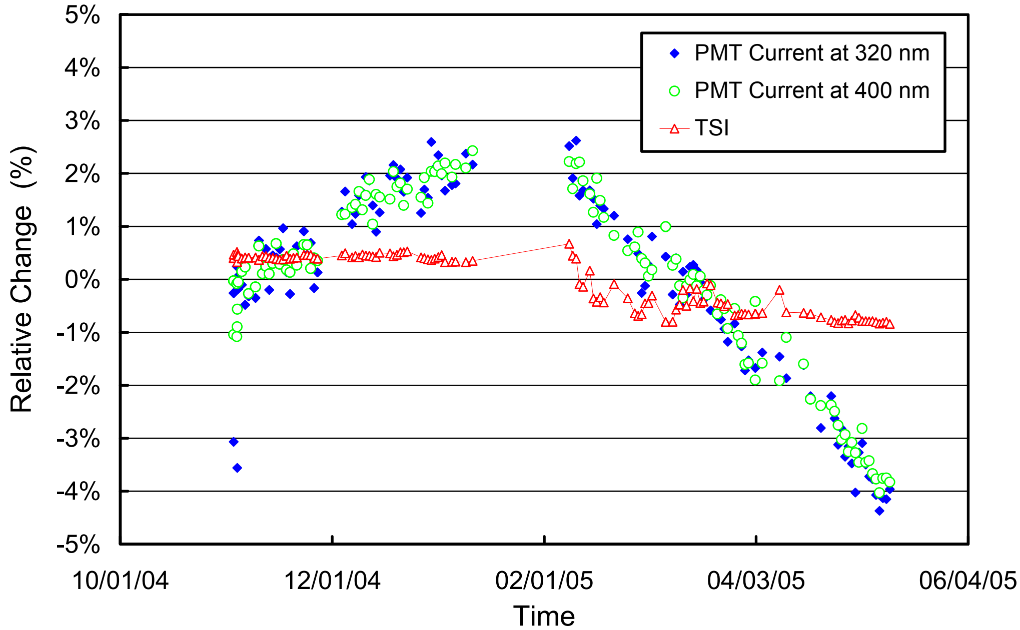

Figure 5.7.3. *Time-series of TSI signal and PMT currents at 320 and 400 nm during measurements of the internal reference lamp performed at Summit between 11/2/04 and 5/12/05. This period covers the interval when the 2nd response lamp was installed.*

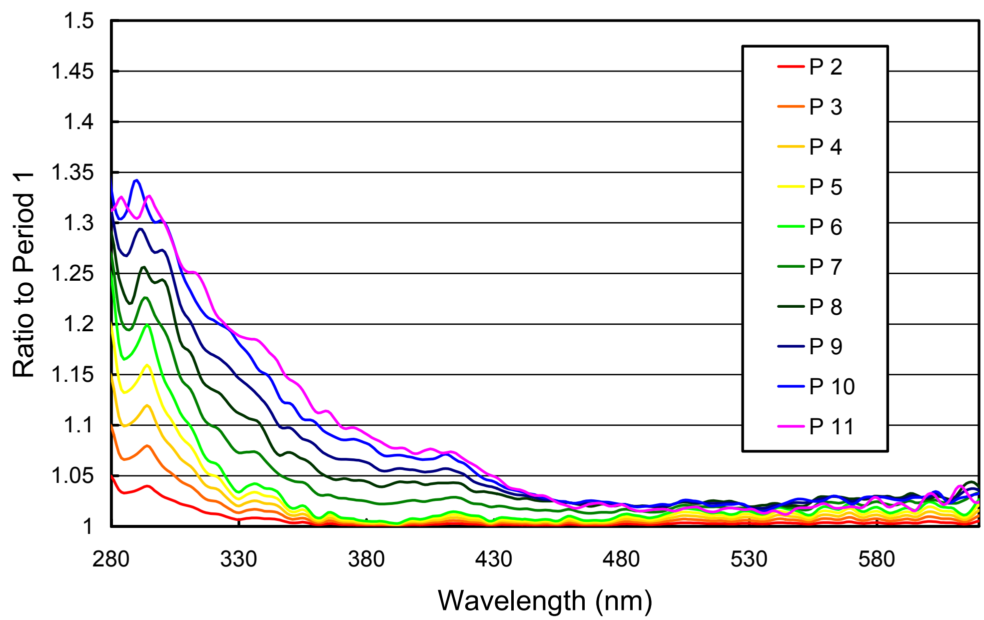

Figure 5.7.4. *Ratios of irradiance assigned to the internal reference lamp in Periods P 2 – P 11, referenced to the irradiance of Period P 1. All calibration functions were smoothed with an approximating spline.*

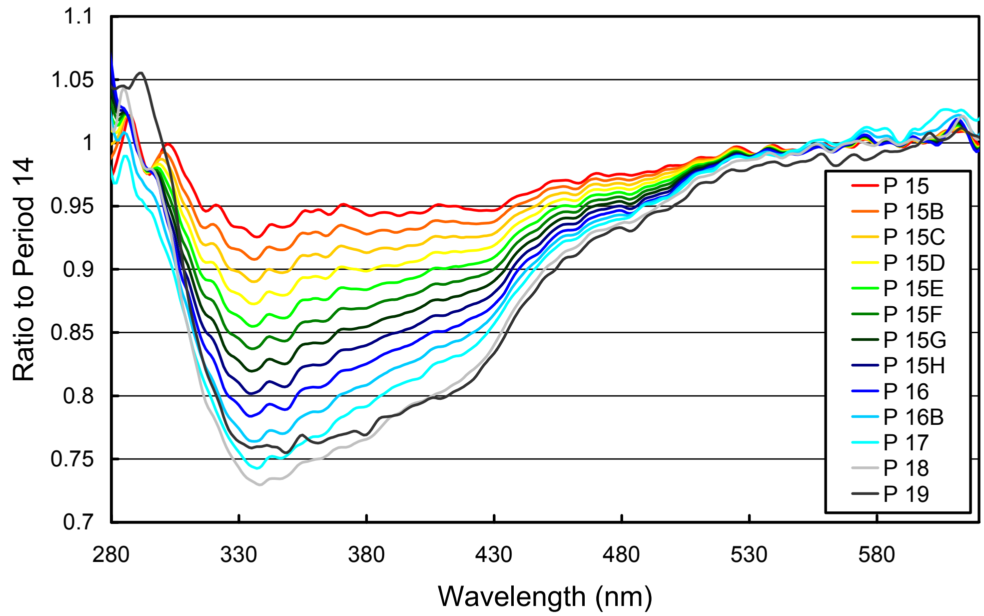

Figure 5.7.5 *Ratios of irradiance assigned to the internal reference lamp in Periods P 15 - P19, referenced to the irradiance of Period P 14. All calibration functions were smoothed with an approximating spline.*

5.7.3. Wavelength Calibration

Wavelength stability of the system was monitored with the internal mercury lamp. Figure 5.7.6 shows the differences in the wavelength offset of the 296.73 nm mercury line between pairs of consecutive wavelength scans for the period 8/15/04 – 5/12/05. In total, 222 scans were evaluated. For 98.7% of the scans is the difference in the wavelength offset to neighboring scans less than ±0.0055 nm. 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 to the use of high-resolution optical encoders that are used in a closed feedback loop with the stepper motor controllers. Changes larger than ±0.01 nm were caused by operator intervention and affected data were adjusted accordingly.

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 (Section 4.2.2.2). Due to good wavelength stability of the system, only one correction function had to be applied for the entire reporting period. This function is shown in Figure 5.7.7. Since the positions of the monochromator's gratings are determined by optical encoders, irregularities in the monochromator drive are inconsequential. This explains the smoothness of the function. Most of the variations observed are artifacts of the correlation algorithm, which has an uncertainty of about 0.015 nm.

After the data was corrected using this function, the wavelength accuracy of all scans with solar zenith angles smaller than 89° was verified with the "Version 2" Fraunhofer correlation algorithm. The results are shown for four UV wavelengths in Figure 5.7.8. Residual shifts are typically smaller than ±0.05 nm. A more detailed analysis reveals that wavelength shifts are smaller than ±0.025 nm for 99% of all scans. Few outliers occur when spectra are affected by changing cloud cover. The wavelength stability is not worse during cloudy conditions, but the validation is subject to larger uncertainties.

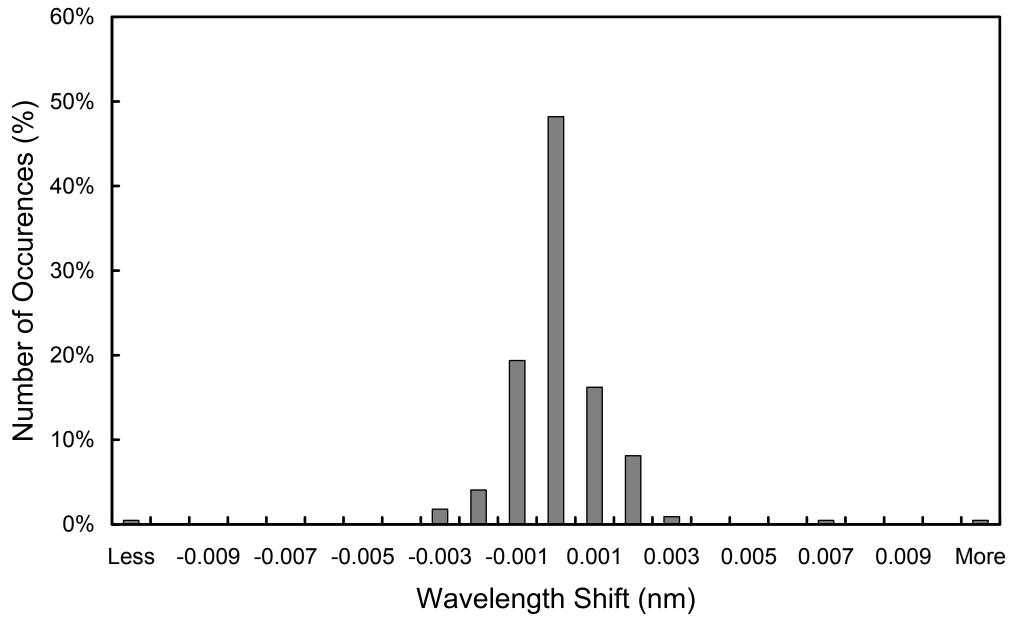

Figure 5.7.6. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans for the period 8/15/04 – 5/12/05. The labels of the horizontal axis give the center wavelength shift for each column. The 0-nm histogram column covers the range from -0.0005 to +0.0005 nm. "Less" means shifts smaller than -0.0105 nm; "more" means shifts larger than 0.0105 nm.*

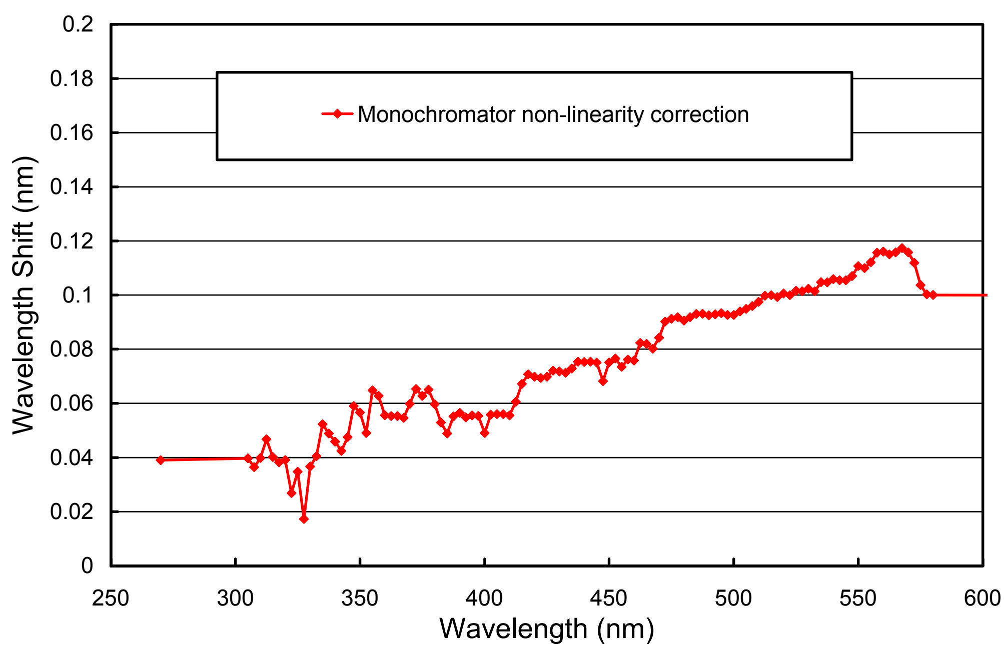

Figure 5.7.7. *Monochromator non-linearity correction functions for the Volume 14 period at Summit.*

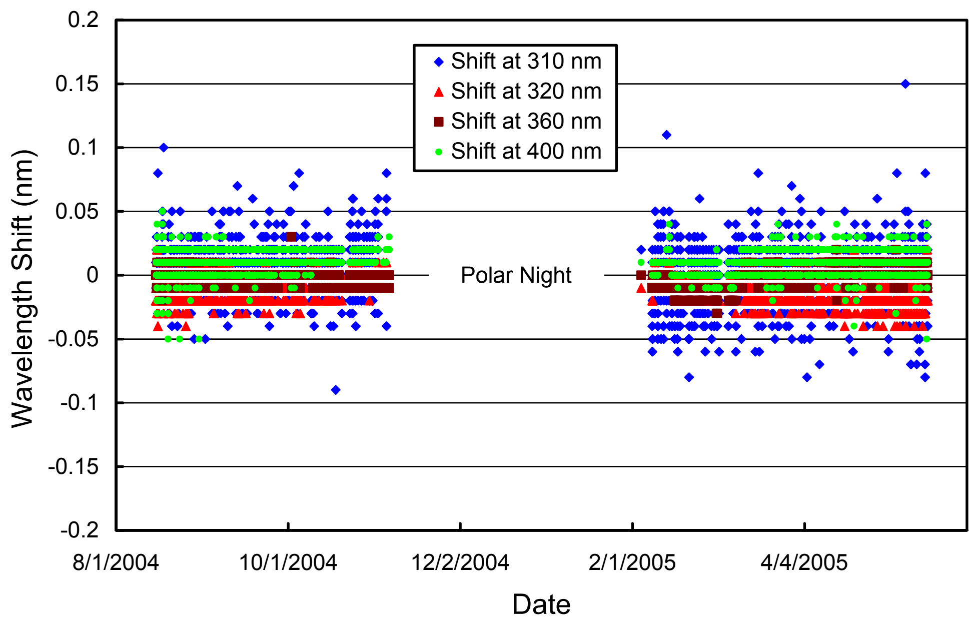

Figure 5.7.8. *Wavelength accuracy check of final data at four wavelengths in the UV by means of Fraunhofer-line correlation. All measurement at solar zenith angles larger than 89° have been evaluated.*

5.7.4. Missing Data

A total of 9335 scans are part of the published Summit Volume 14 dataset. About 22% of all possible scans were lost due to technical problems. Missing periods are summarized in Table 5.7.1.

Table 5.7.1. Missing solar scans in the Summit Volume 14 dataset.

Period	Reason
9/9/04, morning	Filename labeling error
9/18/04, extended period	Program not running – likely software problem
9/28/04, extended period	Program not running for unknown reasons
10/8/04, all day; 10/9/04, part day	Program not running for unknown reasons
10/13/04, afternoon	Absolute scan
10/18/04, morning	Program not running for unknown reasons
10/20/04 – 10/22/04	Intermitted connection to internal lamp; program “hung” when trying to switch on the lamp
10/28/04, afternoon	Program not running for unknown reasons
11/2/04, part day; 11/3/04, all day	Replacement of response lamp
11/6/04, afternoon	Training of research associate
1/23/05 – 2/2/05	Mercury lamp on during solar scans
2/5/05 – 2/7/05	Data defective; replacement of mercury lamp control board
2/13/05, morning	Peripheral device (Agilent 34970A) “hung”
2/19/05, extended period	PMT HV set to zero volt
2/20/05, all day	Data defective
2/26/05, morning	Data missing for unknown reasons
3/4/05, afternoon; 3/7/05, morning	PMT HV set to zero volt, timeout from electrometer, no raw data
3/10/05, afternoon	Missing for unknown reasons
3/22/05, morning	Software “hung”
3/26/05, evening; 3/27/05 all day	Software “hung”

4/4/05, afternoon	Missing for unknown reasons
4/7/05, all day	Data defective for unknown reasons
4/11/05, all day	Missing for unknown reason
4/13/05, morning	Data defective for unknown reasons
4/16/05, all day	Mismatch of Filename and Time
4/23/05, all day; 4/24/05, morning	Missing for unknown reasons
5/12/05, partial day	Software "hung"

5.7.5. GUV Data

The GUV-511 radiometer, which is installed next to the SUV-150B, was calibrated against final 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 5.7.9. shows a comparison of GUV-511 and SUV-150B erythemal irradiance based on final Volume 14 data. For solar zenith angles smaller than 80°, measurements of the two instruments agree to within ±2% (±1σ). This good agreement confirms that the drifts of the SUV-150B discussed in Section 5.7.2 have been satisfactorily removed by adjusting the instrument's calibrations. We advise data users to use SUV-150B rather than GUV-511 data whenever possible, in particular for low-Sun conditions.

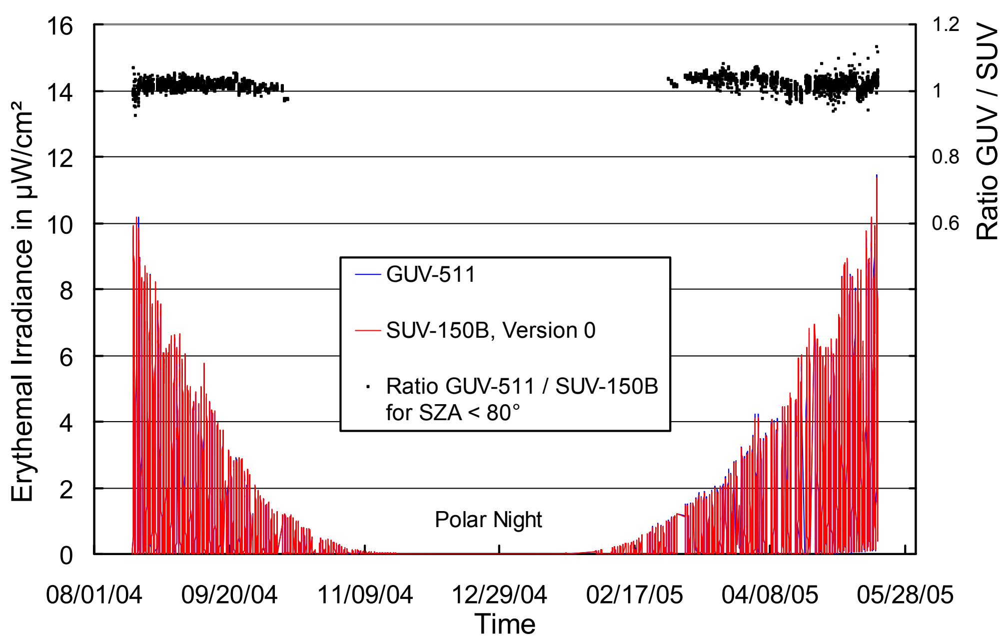

Figure 5.7.9. *Comparison of erythemal irradiance measured by the SUV-150B spectroradiometer and the GUV-511 radiometer. SUV-150B measurements are based on "Version 0" (cosine-error uncorrected) data.*

Figure 5.7.10 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. Both data sets agree on average to within 1%. For SZA larger than 80°, GUV-511 data become unreliable and should not be used.

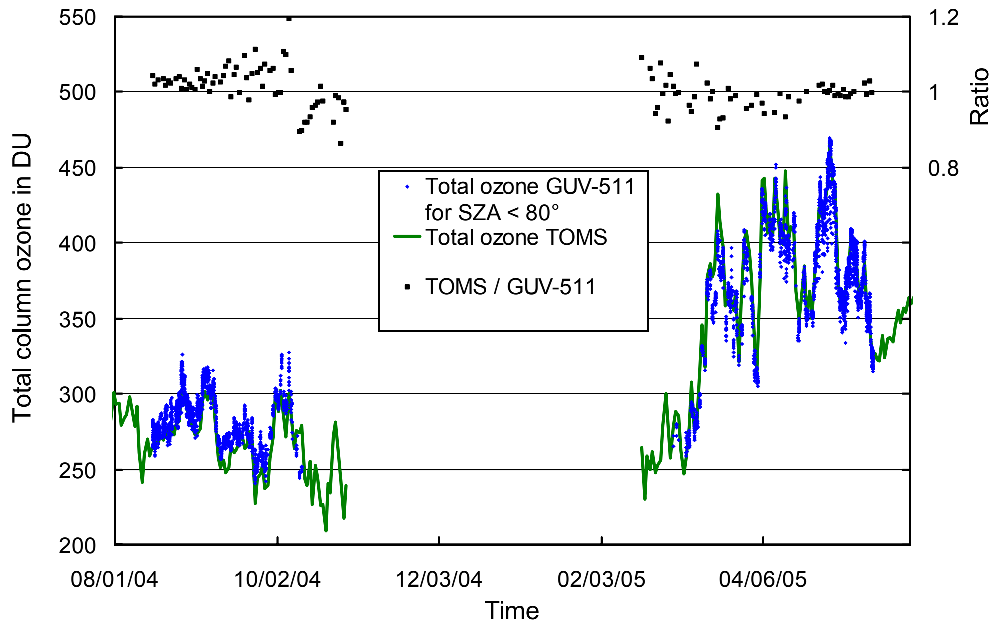

Figure 5.7.10. *Comparison of total column ozone measurements from GUV-511 and NASA/TOMS Earth Probe satellite. GUV-511 measurements are plotted in 15 minute intervals. For calculating the ratio of both data sets, only GUV-511 measurements concurrent with the TOMS overpass data were evaluated.*