5.7. Summit, Greenland (8/2/05 – 11/24/06)

This section describes quality control of solar data recorded by the SUV-150B spectroradiometer at Summit Camp, Greenland, between 8/2/05 and 11/24/06. Opening calibrations took place on 8/2/05. The end of the data series is marked by the beginning of the Polar Night, when is the Sun remains more than 3° below the horizon.

This is the second volume presenting data from the SUV-150B spectroradiometer at Summit. Getting a new and complex system at a new site up and running is always a challenge. Some problems identified during the first year of operation (2004/2005) were addressed during the site visit in 2005. The instrument control software was continuously advanced during 2005 and 2006, which improved instrument reliability further. A total of 25485 scans are part of the published Summit Volume 15 dataset. Only 2.2% of all scans that could have been recorded were lost due to the technical problems. A more detailed breakdown of missing scans can be found in Section 5.7.4.

Final data from the SUV-150B have been successfully compared with measurements of the collocated GUV-511 multi-filter radiometer. Data were also checked with radiative transfer calculations, confirming their good quality.

The following problems affected system performance during the reporting period. Most issues could be corrected during data processing, and the effect on published data is therefore small.

Drift of instrument responsivity due to change of collector throughput
The irradiance collector of the SUV-150B spectroradiometer consist of a baffled integrating sphere. The originally installed sphere was internally coated with Barium sulfate. The sphere's throughput showed large drifts during the 2004/2005 season, which could be attributed to degradation of the coating. Details may be found in the Volume 14 Operations Report. A new sphere was designed in response to the problem, and installed on 8/16/05. The interior walls of the new sphere are lined with solid shells of a Polytetrafluorethylene (PTFE) material, which is known for superior stability.

The old sphere was still in place between 8/2/05 and 8/16/05 and large responsivity changes were observed during this period. These drifts were corrected by adjusting the instrument's calibration files on a daily basis. Published SUV data were validated with measurements of the collocated GUV-511 multifilter radiometer. The comparison indicates that the drift-related uncertainty of SUV data from this period is about 2%.

The throughput of the new PTFE-lined sphere was stable at the ±4% level between August 2005 and May 2006. From May 2006 onward, the throughput started to decrease monotonously. Drifts were generally larger at shorter wavelength and could be corrected during data processing. The reasons for these drifts are unknown as of this writing.

Drift of instrument responsivity not related to collector throughput
The PMT signal during measurements of the internal 45-Watt lamp changed by about 15% between February and September 2006. This drift is indicative of contamination of the instrument's optics (beam splitters, relay lens, monochromator), or could have been partially caused by changes of the PMT's sensitivity. It was not possible at this time to associate the drift with a single component. The drift was very monotonous over time and could be corrected during data processing.

Failure of lamp power supply
Starting on 12/21/05, the lamp power supply reported errors and response scans with the internal lamp could no longer be performed. Power supply and lamp circuit were repaired in the first half of February. The problem occurred during the winter months when only few solar scans were recorded. The quality of these scans was confirmed with measurements of the GUV-511 radiometer.

Problems storing data from the internal Total Scene Irradiance (TSI) sensor
Data from the TSI sensor was not always correctly recorded and data from several days are missing in published data bases.

Software problems
The SUV-150B system control software reported errors on several occasions and stopped recording of data, leading to some loss of data. The software was continuously improved in response to these problems and ran very stable in 2006.

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. Lamp 200W017 was used as traveling standard at the start of the season. This lamp was calibrated by Optronic Laboratories on 3/19/01.

Figure 5.7.1 shows a comparison of lamps 200W030 and 200W017 on 8/2/05 and 8/10/05. The calibration of the two lamps is very consistent. Figure 5.7.2 shows a similar comparison between lamps 200W027 and 200W017. There is a systematic bias of about 1-2% in the UV and 0-1% in the visible. A similar bias has been observed during previous comparisons of the two lamps. The bias was also evident in additional comparisons of lamp 200W027 with other lamps calibrated by Optronic Laboratories in March 2001. We therefore decided to recalibrate lamp 200W027 against the site standard 200W030, using all scans of lamps 200W027 and 200W030 that were executed at Summit during the 2005/2006 season. The new calibration of lamp 200W027 was also checked against the traveling standard 200W017, and very good agreement was found.

Lamp 200W027, with the new calibration applied, was compared with lamp 200W030 eight times during the reporting period. The results are shown in Figure 5.7.3. The calibrations of the two lamps were very consistent for all events and no drifts over time were observed.

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

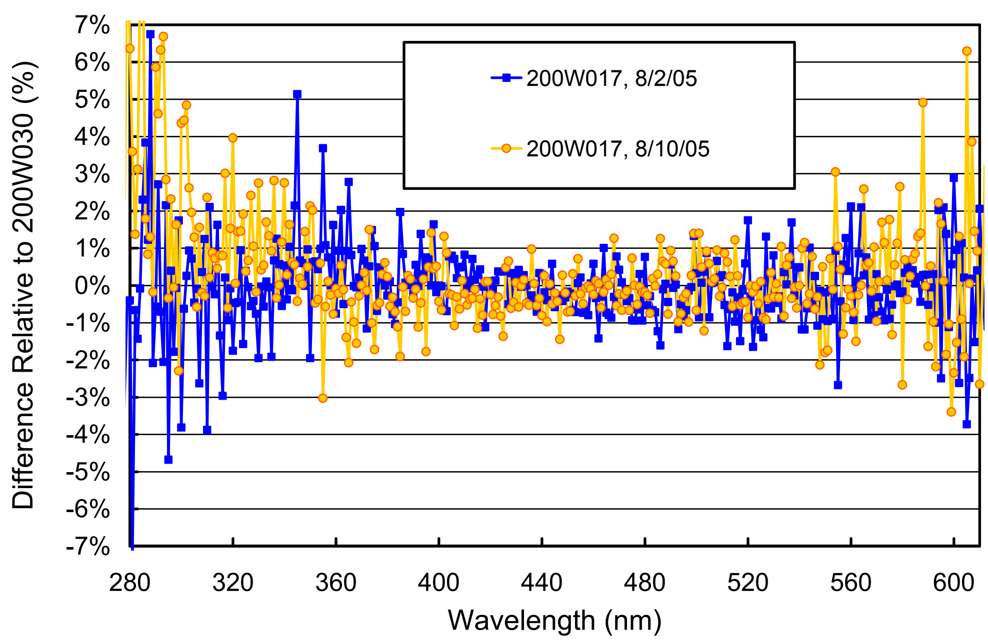

Figure 5.7.1. *Comparison of lamps 200W017 and 200W030.*

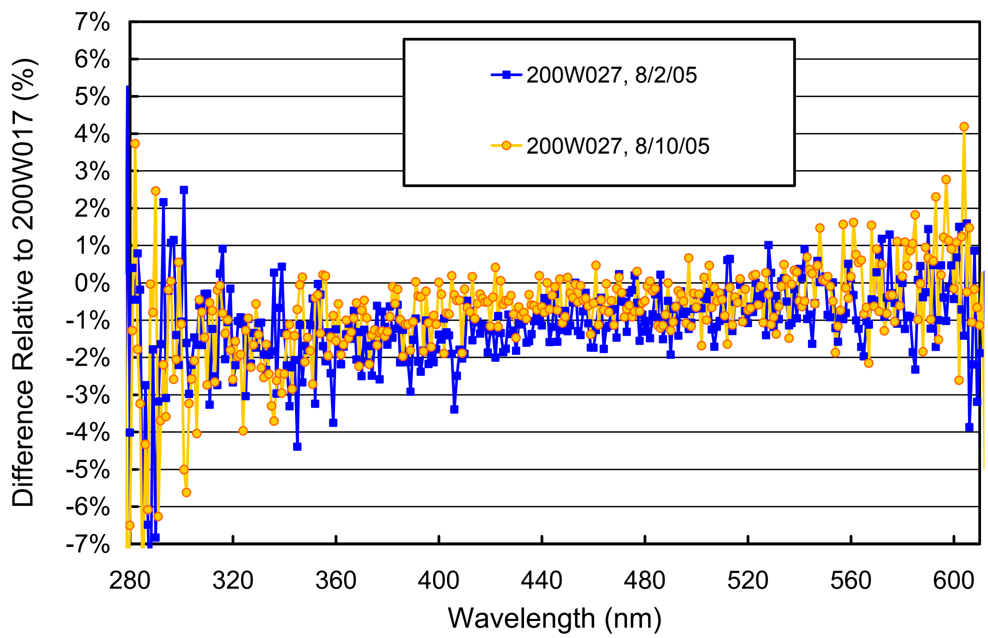

Figure 5.7.2. *Comparison of lamps 200W030 and 200W017. The original calibration of lamp 200W027 from 3/28/01 was applied.*

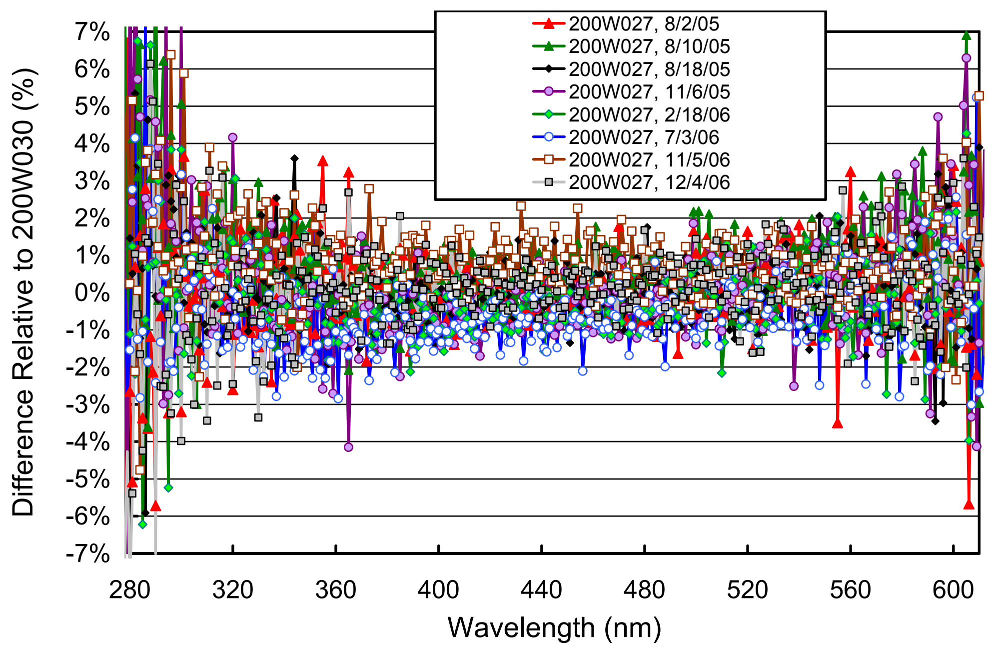

Figure 5.7.3 *Comparison of lamps 200W027 and 200W030 at eight times during the 2005/2006 season at Summit. The new calibration of lamp 200W027 was applied.*

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.

To assess the stability of the new PTFE-lined sphere, we analyzed the signal of the four filtered photo diodes that are integral to the sphere. The photo detectors point to the sphere's central baffle and are mounted around the exit port of the sphere (Section 2). Data from the photo detectors are not affected by possible changes of other system components such as the optical fiber, which connects the sphere with the remainder of the system, or changes in monochromator throughput. Signals of the photo detectors are also recorded during absolute scans when an external 200-Watt lamps illuminates the sphere. Signals should ideally be constant from one calibration event to the next, assuming that the irradiance from the external lamp does not change over time. Figure 5.7.4 shows signals of the four photo detectors as a function of time. Data were normalized to the signals recorded on 8/18/05, the day after the new PTFE-lined sphere was installed. Results indicate that the sphere's throughput was stable at the ±4% level between August 2005 and May 2006. From May 2006 onward, the throughput started to decrease monotonously. Drifts were generally larger at shorter wavelength: the change is 20% at 320 nm, 13% at 340 nm, and ±4% at 380 and 490 nm. Measurements of the TSI sensor were also analyzed, and no significant changes were observed. Drifts could be corrected during data processing. The cause of these changes is unknown as of this writing. Since the throughput was stable for nine month before it started to decrease, deterioration of the PTFE material is unlikely. Contamination or condensation of water are possible explanations. Results are consistent with the analysis of absolute scans (Figure 5.7.9). It can therefore be excluded that drifts are caused by possible changes in the sensitivity of the photo detectors.

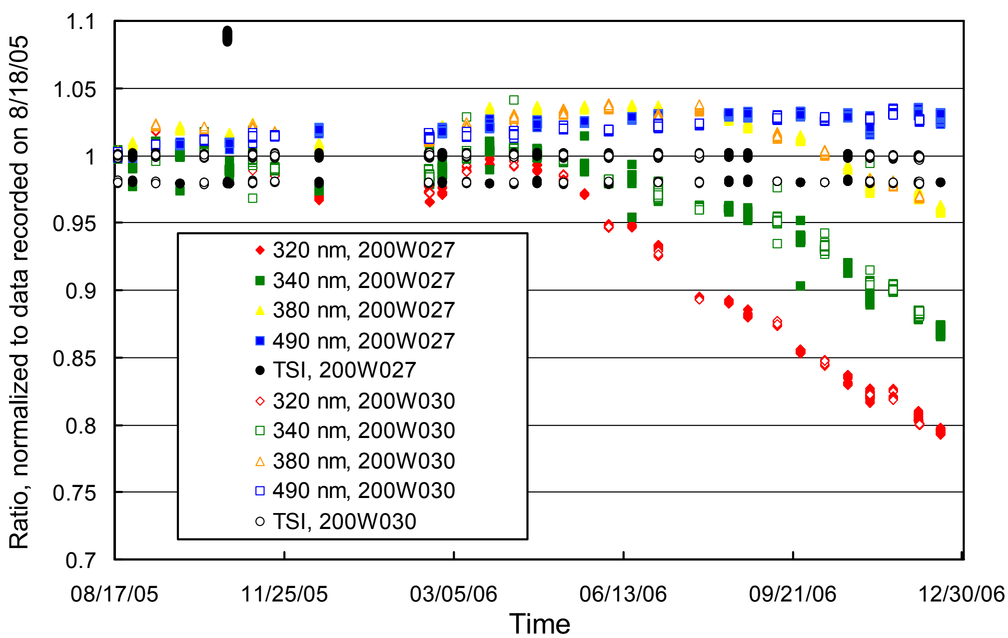

Figure 5.7.4. *Analysis of change in throughput of the new PTFE-lined integrating sphere, which was installed on 8/16/05. Change in throughput was assessed by analyzing data of photo detectors that are mounted around the sphere's exit port. Signals of the detectors were recorded during absolute scans when 200-Watt calibration standards were illuminating the sphere. Measurements are normalized to data recorded on 8/18/05. Data associated with the calibration standards 200W027 and 200W030 were analyzed separately. Measurements of the TSI sensor are also shown.*

Figure 5.7.5 shows changes in TSI readings and PMT currents at 320 and 400 nm, derived from response scans performed between 8/3/05 and 12/20/05. All parameters are stable to within ±2%, indicating good performance of monochromator and PMT. Starting on 12/21/05, the lamp power supply reported errors and response scans could no longer be performed. This is of little consequence since the error occurred during winter months when only few solar scans were executed. Power supply and lamp circuit were repaired in the first half of February. Solar scans up to 2/12/06 were "paired" with the response scan performed on 12/20/05. To check the quality of SUV data for the period when no response scans were available, we compared SUV measurements with data from the GUV-511 radiometer. The two data sets were consistent to within ±2%.

Figure 5.7.6 shows changes in TSI readings and PMT currents at 320 and 400 nm for the period 2/16/06 and 12/20/06. This is the period following the repair of the power supply. TSI measurements during this period decreased by 5%, indicating that the internal lamp became dimmer. Measurements of the PMT decreased by ±15% between February and September and increased by 5% thereafter. The reason for this change is currently unknown but could be caused by changes in monochromator throughput, PMT sensitivity, or contamination of other optical components. Drifts were corrected during data processing.

The new PTFE-lined sphere was installed on 8/16/05. Volume 15 data from the period 8/2/05 - 8/16/05 were still recorded with the old sphere and changes of up to 12% in the sphere's throughput were observed during this period. There were not enough absolute scans available to correct the loss in sensitivity due to the rapid degradation. We therefore used data from the GUV-511 radiometer to track and correct drifts in SUV data. This approach takes advantage of the GUV's good stability. Corrected SUV data are consistent to within ±2% with GUV measurements and results from radiative transfer calculations. We are therefore confident that published data from this period are only very little affected by the drift. Figure 5.7.7 presents ratios of irradiance spectra applied to the internal lamp during 8/2/05 - 8/16/05, referenced to the spectrum applied on 8/2/05 (Period P1). The drift is largest between 320 and 340 nm. More information on calibrations applied during this period is provided in Table 5.7.1.

The new integrating sphere was considerably more stable than the previously installed sphere. However, also its throughput changed in the UV, and this required adjustments of the instrument's calibration. We used again comparisons with GUV data and results from the radiative transfer model to assess the quality of corrected SUV data. We conclude that the uncertainty of published data due to the change of the sphere's throughput is smaller than ±3% at all times.

Figure 5.7.8 presents ratios of irradiance spectra applied to the internal lamp between mid-August 2005 and mid-February 2006 (Periods P4B – P6B), referenced to the spectrum of scans executed on 8/18/05 (Period P4). The system responsivity changed by 0-7% during this time. Some of this drifts is also attributable due to the small dimming of the internal lamp (see also Figures 5.7.5. and 5.7.6).

Figure 5.7.9. shows ratios of irradiance spectra applied to the internal lamp between February and December 2006 (Periods P7 – P17), referenced to the spectrum for Period P7 (February 2006). The irradiance applied to the lamp increased for wavelengths below about 340 nm and decreased above 380 nm. The increase at short wavelength is due to decrease of the sphere's throughput; the decrease at long wavelengths is likely caused by changes or contamination of system components other than the integrating sphere. The exact cause is unknown.

Table 5.7.1. Calibration periods for Summit Volume 15.

Period name	Period range	Number of absolute scans	Remarks
P1	08/02/2005	3	
P1B	08/03/2005	0	Interpolated from Period P1, P2
P1C	08/04/2005	0	Interpolated from Period P1, P2
P1D	08/05/2005	0	Interpolated from Period P1, P2
P1E	08/06/2005	0	Interpolated from Period P1, P2
P1F	08/07/2005	0	Interpolated from Period P1, P2
P2	08/08/2005 - 08/09/2005	2	
P3	08/10/2005 - 08/16/2005	3	
P4A	08/17/2005 - 08/18/2005	2	Scaled with GUV data
P4B	08/19/2005 - 08/21/2005	2	Scaled with GUV data
P5A	08/22/2005 - 09/14/2005	2	Scaled with GUV data
P5B	09/15/2005 - 09/30/2005	2	Scaled with GUV data
P6A	10/01/2005 - 12/31/2006	6	
P6B	01/01/2006 - 02/13/2006	0	Period P6A, scaled with GUV data
P7	02/14/2006 - 02/22/2006	2	
P8	02/23/2006 - 03/19/2006	2	
P9	03/20/2006 - 04/16/2006	2	
P10	04/17/2006 - 05/14/2006	2	
P11	05/15/2006 - 05/28/2006	1	
P12	05/29/2006 - 07/9/2006	4	
P12B	07/10/2006 - 07/20/2006	0	Interpolated from Period P12, P13
P13	07/21/2006 - 09/02/2006	3	
P14	09/03/2006 - 10/02/2006	2	
P15	10/03/2006 - 10/26/2006	2	
P15B	10/27/2006 - 11/01/2006	0	Interpolated from Period P15, P16
P16	11/02/2006 - 11/19/2006	2	
P17	11/20/2006 - 12/12/2006	2	

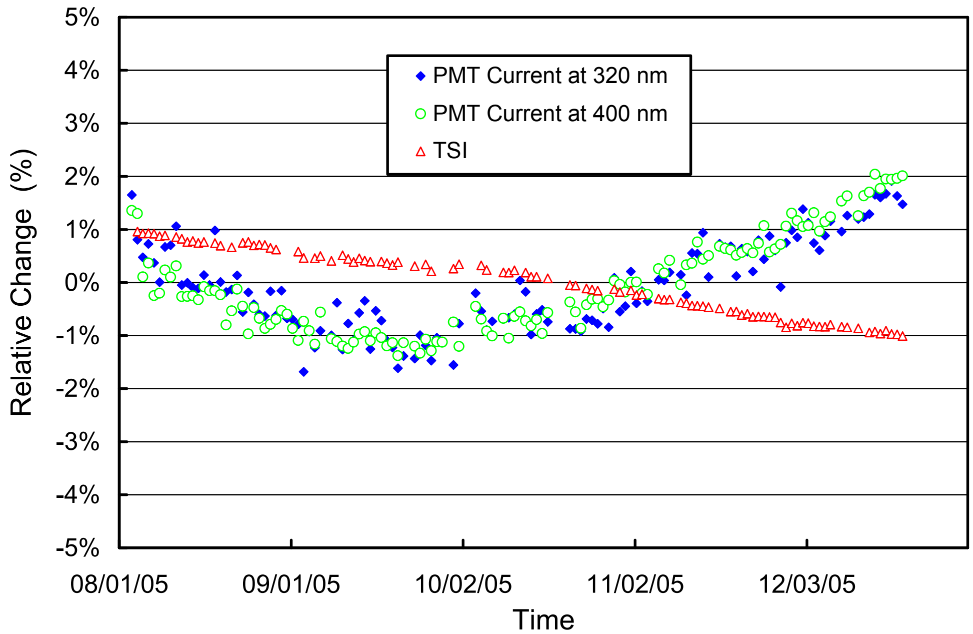

Figure 5.7.5. *Time-series of TSI signal and PMT currents at 320 and 400 nm during measurements of the internal reference lamp performed at Summit between 8/3/05 and 12/20/05. On 12/21/04, the lamp power supply became defective.*

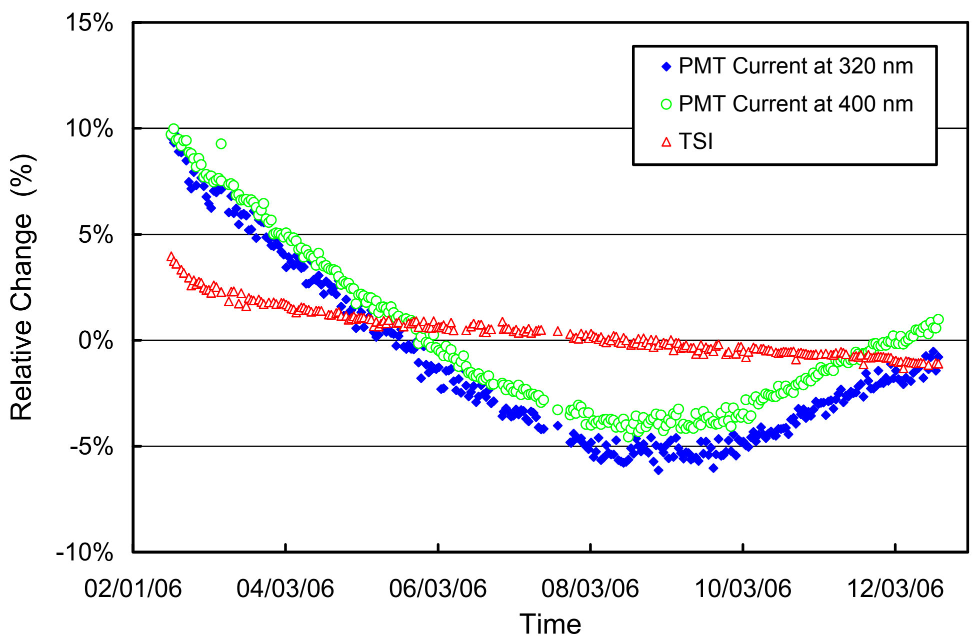

Figure 5.7.6. *Time-series of TSI signal and PMT currents at 320 and 400 nm during measurements of the internal reference lamp performed at Summit between 2/16/06 and 12/20/06. This period covers the interval following repair of the power supply.*

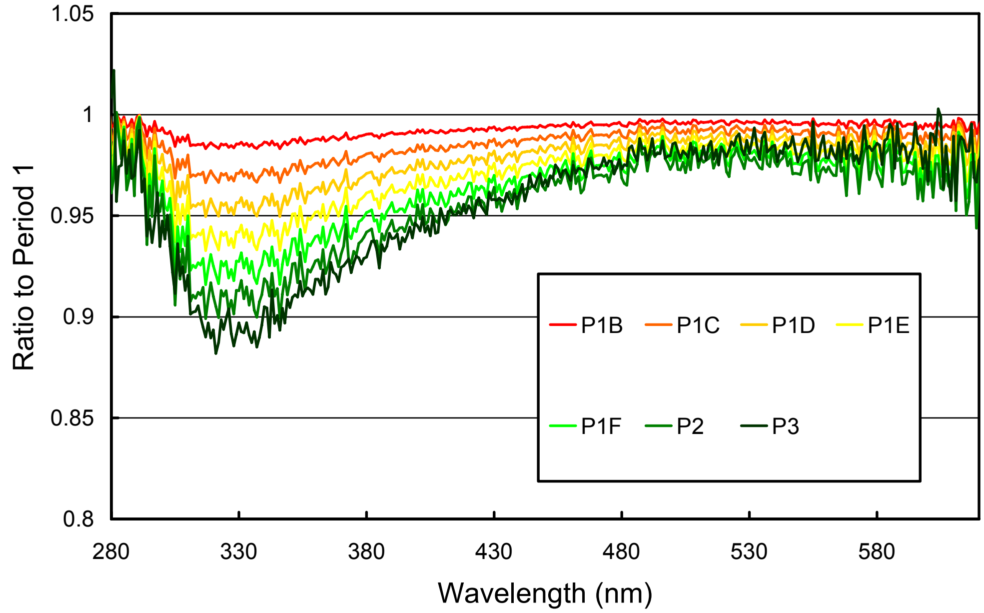

Figure 5.7.7. *Ratios of irradiance assigned to the internal reference lamp in Periods P1B – P3, referenced to the irradiance of Period P1. Data cover the period 8/2/05 - 8/16/05. The old sphere was installed during this time.*

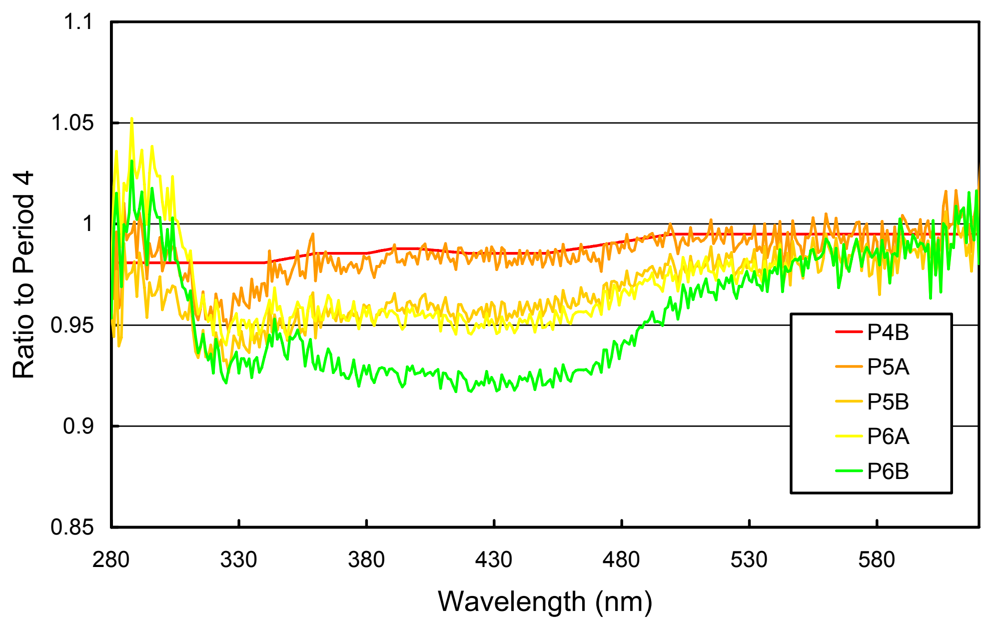

Figure 5.7.8. *Ratios of irradiance assigned to the internal reference lamp in Periods P4B – P6B, referenced to the irradiance of Period P4. Data cover the period 8/17/05 - 2/13/06. The start marks the day when the new sphere was installed. The end coincides with the repair of the lamp power supply and lamp circuit.*

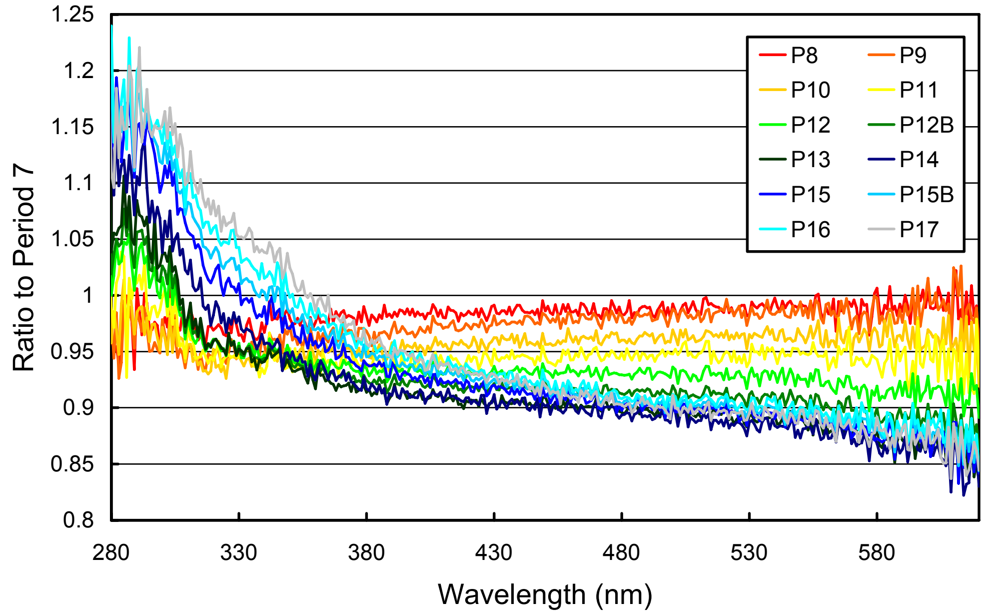

Figure 5.7.9. *Ratios of irradiance assigned to the internal reference lamp in Periods P8 – P17, referenced to the irradiance of Period P7. Data cover the period 2/14/06 - 12/12/06. The new integrating sphere was installed during this period.*

5.7.3. Wavelength Calibration

Wavelength stability of the system was monitored with the internal mercury lamp. Figure 5.7.10 shows the differences in the wavelength offset of the 296.73 nm mercury line between pairs of consecutive wavelength scans for the period 8/2/05 – 12/10/06. In total, 469 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 due 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.

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., 2004a; see also 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 5.7.11. 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 noontime scans was verified with the "Version 2" Fraunhofer correlation algorithm. The results are shown for four UV wavelengths in Figure 5.7.12. Residual shifts are typically smaller than ±0.05 nm. A more detailed analysis reveals that wavelength shifts are smaller than ±0.02 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.

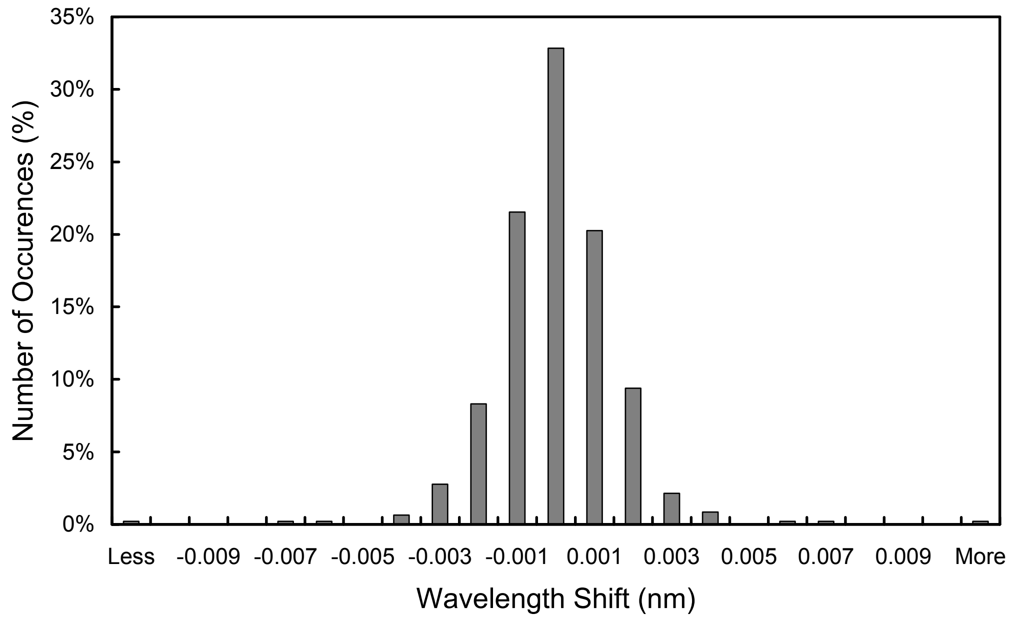

Figure 5.7.10. *Differences in the measured position of the 296.73 nm mercury line between consecutive wavelength scans for the period 8/2/05 – 12/10/06. The labels of the horizontal axis give the center wavelength shift for each column. The 0-nm histogram column covers the range from -0.0005 to +0.0005 nm. "Less" means shifts smaller than -0.0105 nm; "more" means shifts larger than 0.0105 nm.*

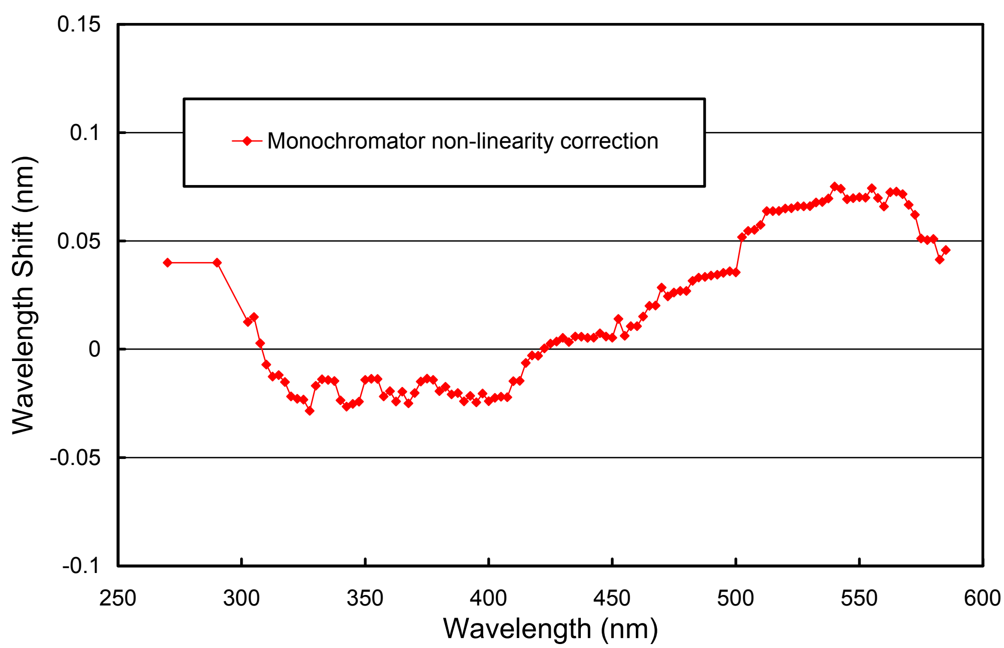

Figure 5.7.11. *Monochromator non-linearity correction functions for the Volume 15 period at Summit.*

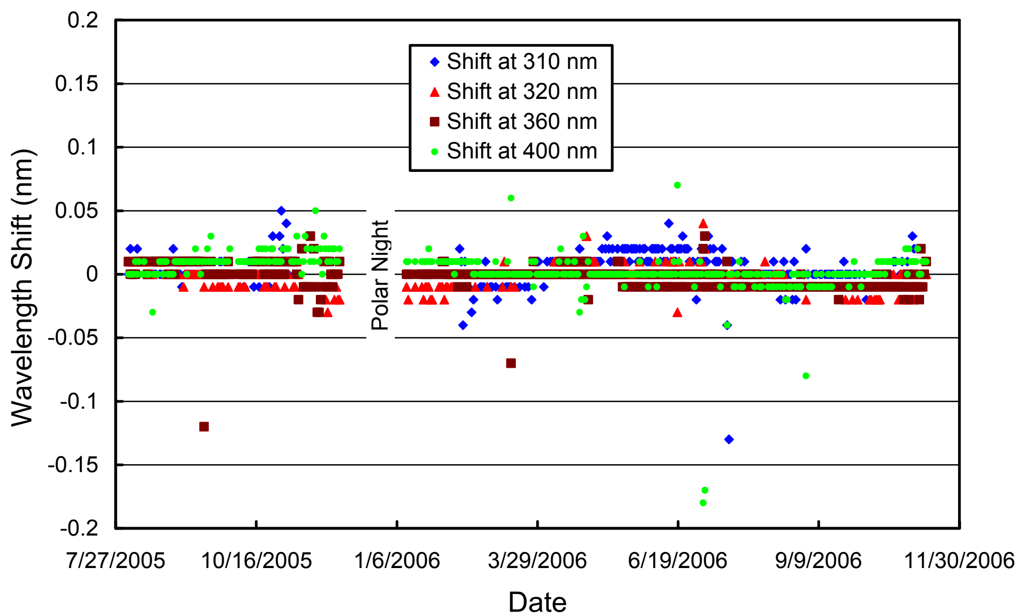

Figure 5.7.12. *Wavelength accuracy check of final data at four wavelengths in the UV by means of Fraunhofer-line correlation. All noontime measurement have been evaluated.*

5.7.4. Missing Data

A total of 25485 scans are part of the published Summit Volume 15 dataset. Only 2.2% of all possible scans were lost due to technical problems. Missing periods are summarized in Table 5.7.2.

Table 5.7.2. Missing solar scans in the Summit Volume 15 dataset.

Period	Number of scans	Reason
		Calibration scans
Throughout season	672	Response scans
Throughout season	469	Wavelength scans
Throughout season	204	Absolute scans
		Operational support
08/10/2005	10	Operator training
08/16/2005	32	Installation of new integrating sphere
08/18/2005	9	Installation sensors for relative humidity and external temperature
		Technical problems
Throughout season	40	Solar scans with excess lengths, preventing start of next scan
Throughout season	39	Software coding and testing*
09/07/2005	22	Corrupt data (mismatch between date and filename)
09/22/2005	27	Software can't write to database (Runtime error 3704)
09/29/2005	24	Software halted due to communication problem with electrometer
10/02/05 - 10/04/05	104	Software halted due to communication problem with electrometer
10/05/05	11	Software halted when running a response scan
10/08/05	17	Software halted due to communication problem with electrometer
11/05/2005	17	Software can't write to database (Runtime error 3704)

11/09/2005	2	Missing for unknown reasons
11/11/2005	10	Replacement of fan for Eppley pyranometer
11/16/2005	11	Software can't write to database (Runtime error 3704)
01/28/2006 - 01/30/2006	44	Troubleshooting lamp power supply / lamp circuit
02/13/2006	14	Troubleshooting lamp power supply / lamp circuit
06/26/2006 - 06/27/2006	89	Software halted when running a response scan
07/16/2006 - 07/17/2006	136	Software halted for unknown reasons

* Additional System Control Software updates were applied during winter when no solar scans were scheduled.

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. GUV data from 2005 were correlated against SUV-150B data from 2005; GUV-data from 2006 are based on a correlation using 2006 SUV-150B data. From the calibrated measurements, data products were calculated (Section 4.3.2). Figure 5.7.13 shows a comparison of GUV-511 and SUV-150B erythemal irradiance based on final Volume 15 data. For solar zenith angles smaller than 80°, measurements of the two instruments agree to within ±2% (±1σ). This good agreement confirms that drifts in SUV-150B data discussed in Section 5.7.2 have been satisfactorily removed by adjusting the instrument's calibrations accordingly. We advise data users to use SUV-150B rather than GUV-511 data whenever possible, in particular for low-Sun conditions.

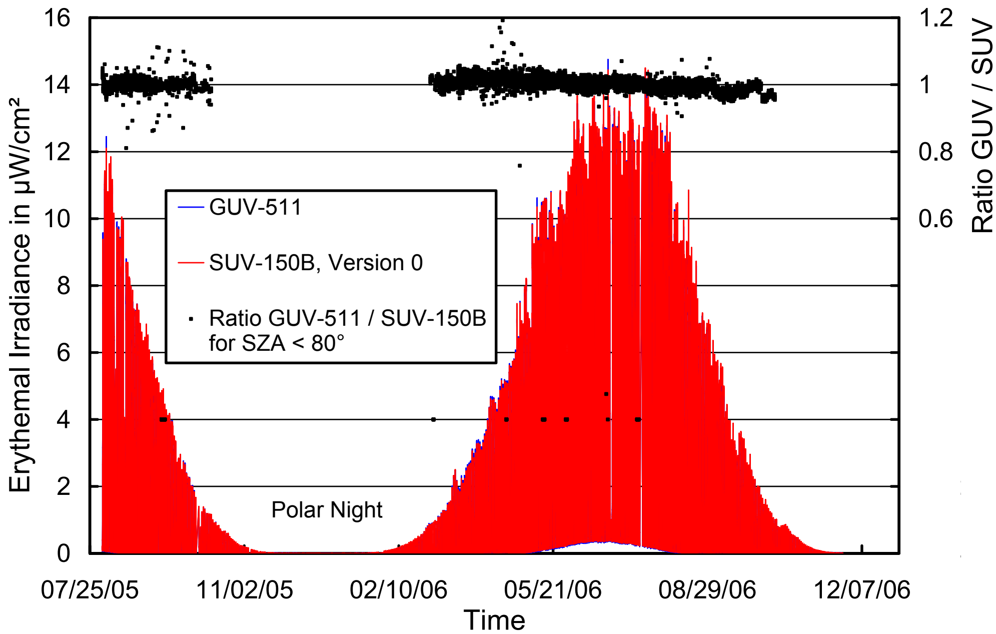

Figure 5.7.13. *Comparison of erythemal irradiance measured by the SUV-150B spectroradiometer and the GUV-511 radiometer. SUV-150B measurements are based on "Version 0" (cosine-error uncorrected) data. Due to the good match of both data sets, most GUV-511 data (blue line) are obstructed by the SUV-150B data (red line).*

Figure 5.7.14 shows a comparison of total ozone measurements from the GUV-511 and the Ozone Monitoring Instrument (OMI). GUV-511 ozone values were calculated as described in Section 4.3.3. The two data sets typically agree to within ±3%, except for March and April 2006, when GUV measurements are systematically smaller than OMI data. The reason for this bias in unknown at this time. For SZA larger than 80°, GUV-511 data become unreliable and should not be used.

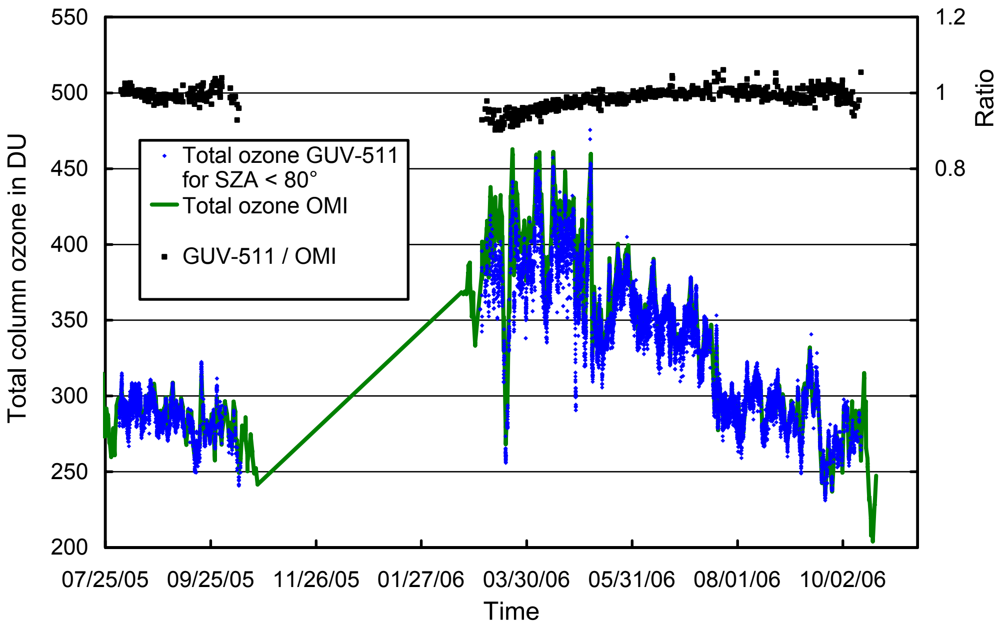

Figure 5.7.14. *Comparison of total column ozone measurements from GUV-511 and OMI. GUV-511 measurements are plotted in 15 minute intervals. For calculating the ratio of both data sets, only GUV-511 measurements concurrent with the OMI overpass were evaluated.*